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Vol. I

TRANSCRIPT OF RECORD

Supreme Court of the United States

OCTOBER TERM, 1940

No. 666

DETROLA RADIO AND TELEVISION CORPORATION, PETITIONER,

vs.

HAZELTINE CORPORATION

ON WRIT OF CERTIORARI TO THE UNITED STATES CIRCUIT COURT OF APPEALS FOR THE SIXTH CIRCUIT

PETITION FOR CERTIORARI FILED DECEMBER 21, 1940.

CERTIORARI GRANTED FEBRUARY 3, 1941.

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IN THE

District Court Of The United States

For the Eastern District of Michigan
Southern Division

HAZELTINE CORPORATION, *Plaintiff*, *v.* DETROLA RADIO AND TELEVISION CORPORATION, *Defendant.*	In Equity No. 8837 — On Patent Reissue No. 19,744

BILL OF COMPLAINT FOR INFRINGEMENT OF UNITED STATES LETTERS PATENT

(Filed March 3, 1938)

To the Honorable the Judges of the United States District Court for the Eastern District of Michigan:—

The Plaintiff for its Bill of Complaint alleges:

1. That Plaintiff, Hazeltine Corporation, is a corporation duly organized and existing under and by virtue of the laws of the State of Delaware.

2. That Plaintiff is informed and believes, and therefore avers, that the Defendant, Detrola Radio and Television Corporation, is a corporation duly organized and existing under and by virtue of the laws of the State of Michigan and is a citizen and inhabitant of the Eastern District of Michigan, Southern Division.

3. That this is a suit in equity arising under the Patent Laws of the United States for infringement of United States Letters Patent.

4. That prior to the 7th day of July, 1927, Harold A. Wheeler, then being a citizen of the United States and residing in the City of Baltimore, State of Maryland, was the first, true, original and sole inventor of the invention and improvements described and claimed in United States Letters Patent No. 1,879,863, issued September 27, 1932, which invention and improvements were not known or used by others in this country before his invention or discovery thereof and not patented or described in any printed publication in this or any foreign country before his invention or discovery thereof, or more than two years prior to the date upon which he made application for Letters Patent therefor, as hereinafter set forth, and not in public use or on sale in this country for more than two years prior to the date of his said application, and not abandoned and not patented or caused to be patented by himself or his legal representatives or assigns in any country foreign to the United States on an application filed more than twelve months prior to the filing of his said application in this country. That being entitled to a patent for the said invention and improvements under the provisions of the statutes of the United States then in force the said Harold A. Wheeler did on July 7, 1927 duly file in the United States Patent Office an application for Letters Patent therefor which said application was identified as Serial No. 203,879, and that subsequently thereto and during the pendency of said application the said Harold A. Wheeler did on November 13, 1930 duly file in the United States Patent Office, upon requirement of the Commissioner of Patents, a divisional application for United States Letters Patent, which said application is identified as Serial No. 495,386.

5. That on the 6th day of November, 1930, by an instrument in writing, duly executed and delivered, the said Harold A. Wheeler duly assigned and transferred unto Hazeltine Corporation, a corporation of the State of Delaware, his entire right, title and interest in and to the said invention and the said application Serial No. 495,386, which assignment contained a request that the Letters Patent to be granted therefor was to issue to the said Hazeltine Corporation; that on or about November 13, 1930, the said assignment was duly recorded in the Transfers of Patents in the United States Patent Office in Liber G-146, page 696.

6. That thereafter and on the 27th day of September, 1932, all requirements of the statutes of the United States then in force having been duly complied with, Letters Patent of the United States numbered 1,879,863 for the said invention and improvements, signed, sealed and executed in due form of law, were duly issued in the name of Harold A. Wheeler assignor to Hazeltine Corporation, a corporation of Delaware, whereby there was granted to it for the term of seventeen years from the date thereof the right to exclude others from making, using and vending the invention and improvements set forth, described and claimed therein throughout the United States and territories thereof, all of which will more fully and at large appear by reference to said Letters Patent, or a copy thereof ready in court to be produced.

7. That subsequently thereto and on or about September 26, 1934, said United States Letters Patent No. 1,879,863 being partly inoperative and invalid by reason of defective and insufficient specifications and claims and by reason of the patentee claiming as his own invention and discovery more than he had a right to claim as new, and the defect and insufficiency in the specifications

and the error of claiming more than the patentee had a right to claim which rendered said patent partly inoperative arising from inadvertance, accident and mistake without any fraudulent or deceptive intention, the said Harold A. Wheeler, on behalf of and with the assent of Hazeltine Corporation, without unreasonable or unavoidable delay made application, Serial No. 745,651, in writing to the Commissioner of Patents for the reissue of United States Letters Patent No. 1,879,863 aforesaid and surrendered said Letters Patent and paid the fee required by law and in all other respects complied with the requirements of the statutes of the United States in such cases made and provided.

8. That thereafter and on the 29th day of October, 1935, all requirements of the statutes of the United States then in force having been duly complied with, Reissue Letters Patent numbered 19,744 for the same invention as that disclosed in aforesaid original Letters Patent No. 1,879,863 and in accordance with the corrected specifications and claims, signed, sealed, and executed in due form of law, were duly issued to Hazeltine Corporation, a corporation of Delaware, as assignee of Harold A. Wheeler, which Letters Patent is now in full force and effect, whereby there was granted to it for the unexpired part of the term of aforesaid original Letters Patent No. 1,879,863 the right to exclude others from making, using and vending the invention and improvements set forth, described and claimed therein throughout the United States and territories thereof, all of which will more fully and at large appear by reference to said Reissue Letters Patent, or a copy thereof ready in court to be produced.

9. That Plaintiff is now and has been ever since the issuance of the aforesaid Letters Patent No. 1,879,863 and Reissue Letters Patent No. 19,744 in possession of

and vested with full and entire right, title and interest in and to said Letters Patent and of all rights of recovery thereunder.

10. That Plaintiff has expended large sums of money in making the invention and improvements described and claimed in said Reissue Letters Patent No. 19,744 of benefit to the public and profitable to itself and that they have been put into extensive use under license from Plaintiff; that said invention and improvements have been and are of great benefit and advantage to the public and that the public has generally acknowledged and acquiesced in the rights of Plaintiff under said Reissue Letters Patent No. 19,744; that Plaintiff has licensed numerous manufacturers under said Reissue Letters Patent to manufacture and sell Volume Controls employing and embodying the invention and improvements described and claimed in said Reissue Letters Patent.

11. That Plaintiff is informed and believes, and therefore avers, that the Defendant, after the issuance of said Letters Patent No. 1,879,863 as aforesaid and continuing after the issuance of said Reissue Letters Patent No. 19,744 as aforesaid, did make and vend and cause to be vended and is now making and vending and causing to be vended and threatens to continue to make and vend and to cause to be vended, within the Eastern District of Michigan and elsewhere within the United States, radio receiving sets incorporating automatic volume control systems.

12. That Plaintiff is informed and believes, and therefore avers, that the aforesaid radio receiving sets incorporating automatic volume control systems employ and embody the invention and improvements of said Letters Patent No. 1,879,863 and of said Reissue Letters Patent No. 19,744 and that the making and vending by

Defendant of such radio receiving sets and the causing by Defendant of the same to be vended as aforesaid is without license or permission and in violation and infringement of said Reissue Letters Patent No. 19,744.

13. That Plaintiff is informed and believes, and therefore avers, that the Defendant has derived and received and will derive and receive from the aforesaid infringement complained of herein, great gains, profits and advantages, but to what amount Plaintiff is not informed and cannot set fourth; that by reason of said infringement Plaintiff has been and will be deprived of and prevented from receiving, if such infringement is not forthwith restrained by this Court, all of the benefits, advantages, gains and profits to which Plaintiff is lawfully entitled and which it would have derived and received and would now be deriving and receiving but for the aforesaid infringement; that, by reason of the aforesaid infringement, Plaintiff has been and will be irreparably injured and has sustained damages and losses thereby; that the aforesaid infringement has been, and is, effective to encourage, induce, aid and abet others to venture to infringe upon and contribute to the infringement of said Letters Patent and, unless the aforesaid infringement is enjoined by a writ of injunction issuing out of this Court, further irreparable injury, loss or damages will be caused to Plaintiff.

14. That radio receiving sets manufactured by persons making or vending the same under the rights of Plaintiff and employing and embodying the invention and improvements of said Letters Patent were marked ever since the issuance of said original Letters Patent No. 1,879,863 and prior to the issuance of said Reissue Letters Patent by affixing thereto the word "Patent" together with the number thereof and have been marked

ever since the issuance of said Reissue Letters Patent No. 19,744 by affixing thereto the word "Patent" together with the number thereof, all as prescribed by the statutes of the United States.

15. That, prior to the filing of this Bill of Complaint and on or prior to the 3rd day of May, 1933, Defendant was duly notified of the issuance of said Letters Patent No. 1,879,863 and of its infringement thereof, and prior to the filing of this Bill of Complaint and on or prior to the 15th day of June, 1936, Defendant was duly notified of the issuance of Reissue Letters Patent No. 19,744 and of its infringement thereof, all in the manner prescribed by the statutes of the United States in such cases made and provided.

16. That Plaintiff is informed and believes, and therefore avers, that, notwithstanding aforesaid patent marking and aforesaid notice, Defendant has continued and is continuing and threatens to continue said infringement in defiance of Plaintiff's rights as hereinabove alleged.

Wherefore the Plaintiff Prays:

1. That Defendant and its officers, agents, attorneys, and all claiming through or under it, may be perpetually enjoined and restrained by the decree of this Court from directly or indirectly making or causing to be made; using or causing to be used; selling or causing to be sold; or offering or threatening to make, use, or sell; or disposing of in any manner any radio receiving sets incorporating Volume Controls employing or embodying the invention and improvements or involving the use of the said invention and improvements of said Reissue Letters Patent No. 19,744 or any substantial, material or vital part or parts thereof, and from infringing upon or contributing to the infringement of said Letters Patent in any way whatsoever.

2. That a preliminary injunction may issue against said Defendant of the same tenor and to the same effect as hereinabove prayed for in respect to said perpetual injunction.

3. That Defendant may be decreed to account to Plaintiff for all such benefits, advantages, gains and profits, as have accrued, or have been earned, or received, by said Defendant from the aforesaid infringement, and all such benefits, advantages, gains and profits as would have accrued to or been earned by Plaintiff but for the aforesaid infringement, and also all the damages Plaintiff has sustained as a result of the aforesaid infringement, and that the Court will assess the same, or cause them to be assessed under its direction and will increase the same in its discretion as provided by law.

4. That said Defendant may be decreed to pay to Plaintiff the costs, charges and disbursements of this suit.

5. That Plaintiff may have such other and further relief in the premises as equity of the case may require and to the Court may seem meet and just.

Hazeltine Corporation,
By John R. Binns,
Whittemore Hulbert & Belknap,
Solicitors for Plaintiff.

State of New York,
County of New York—ss.

John R. Binns, being duly sworn, deposes and says that he is the Vice-President and Treasurer of the Hazeltine Corporation, the plaintiff named in the foregoing Bill of Complaint; that he has read the same and knows the contents thereof, and that the same is true of his own knowledge except as to the matters stated therein to be on information and belief, and as to those matters he believes it to be true.

John R. Binns.

Subscribed and sworn to before me
this 1st day of March, 1938.
F. O. Reinschmidt,
Notary Public.

(Seal)

ANSWER

(Filed March 21, 1938)

Defendant, for answer to the bill of complaint herein, or to as much thereof as it is advised is material or necessary to be answered, on information and belief says:

1. Defendant denies each and every allegation contained in paragraph 4 of the bill of complaint.

2. Defendant is without information as to the correctness of the allegations contained in paragraph 5 of the bill of complaint, and therefore denies the same.

3. Defendant denies each and every allegation contained in paragraph 6 of the bill of complaint save that it admits having seen what purported to be a copy of Letters Patent No. 1,879,863.

4. Defendant denies each and every allegation contained in paragraph 7 of the bill of complaint.

5. Defendant denies each and every allegation contained in paragraph 8 of the bill of complaint save that it admits having seen what purported to be a copy of Reissue Letters Patent No. 19,744.

6. Defendant is without information as to the correctness of the allegation contained in paragraph 9 of the bill of complaint, and therefore denies the same.

7. Defendant denies each and every allegation contained in paragraph 10 of the bill of complaint.

8. Defendant denies each and every allegation contained in paragraphs 11 and 12 of the bill of complaint.

9. Defendant denies each and every allegation contained in paragraph 13 of the bill of complaint.

10. Defendant denies each and every allegation contained in paragraph 14 of the bill of complaint.

11. Defendant is not at present advised of the correctness of the allegations contained in paragraph 15 of the bill of complaint, and therefore denies the same, leaving plaintiff to its strict proof.

12. Defendant denies each and every allegation contained in paragraph 16 of the bill of complaint.

13. Further answering the bill of complaint, defendant denies that it has infringed said Reissue Letters Patent No. 19,744.

14. Further answering the bill of complaint, defendant, on information and belief, asserts that the said Wheeler Reissue Patent No. 19,744 is wholly void and invalid at law for each of the following reasons:

(a) Because the alleged invention of the said patent was shown and described in printed publications in the United States and countries foreign to the United States before the alleged invention by the patentee and/or more than two years prior to the filing of the application for patent on which said patent issued, as follows:

United States Patents

Affel	1,574,780	Mar. 2, 1926
Bjornson	1,666,676	Apr. 17, 1928
Heising	1,687,245	Oct. 9, 1928
Friis	1,675,848	July 3, 1928
Horton	1,690,300	Nov. 6, 1928
Evans	1,736,852	Nov. 26, 1929
Evans	1,869,323	July 26, 1932
Kupfmuller	1,737,503	Nov. 26, 1929
Espenschied	1,447,773	Mar. 6, 1923
Lowell-Dunmore	1,455,141	May 15, 1923
Slepian	1,455,768	May 15, 1923
Turner	1,455,896	May 22, 1923

Affel	1,511,015	Oct.	7, 1924
Affel	1,511,014	Oct.	7, 1924
Perry	1,536,130	May	5, 1925
Scott-Taggert	1,592,710	July	13, 1926
Falknor	1,698,014	Jan.	8, 1929
Green	1,738,000	Dec.	3, 1929
Schelleng	1,836,556	Dec.	15, 1931

British Patents

172,376	Accepted	Nov.	30, 1921
226,338	"	Dec.	24, 1924
259,664	"	Oct.	14, 1926

French Patents

603,373	Published	Apr.	14, 1926
614,471	"	Dec.	15, 1926

Publications

"Experimental Wire and Wireless Engineer", May 1926, p. 328, published by Steffe & Sons, Ltd., London, E. C. 4

Proceedings of the Institute of Radio Engineers, Vol. 12, 1924, pp. 119-158

Proceedings of the Institute of Radio Engineers, January, 1928, pp. 30-39, Paper by Harold A. Wheeler on "Automatic Volume Control for Radio Receiving Sets"

and others, of which defendant is not at present advised but begs leave to add hereto by proper amendment to this, its answer, together with details thereof, when such information is obtained.

(b) Because the said patent discloses no patentable invention over and/or in view of the state of the art at and prior to the time application for said patent was filed and as illustrated in the instances thereof referred to in paragraph (a) hereof.

(c) Because the patentee surreptitiously or unjustly obtained a patent for that which in fact was the invention of others who were using reasonable diligence in adopting and perfecting the same. In support hereof reference will be made to the following patentees who, prior to the date of filing of the application for the Wheeler patent, had made application for patent showing, describing, and/or claiming the said invention:

Bjornson	1,666,676	Apr. 17, 1928
Heising	1,687,245	Oct. 9, 1928
Horton	1,690,300	Nov. 6, 1928
Evans	1,736,852	Nov. 26, 1929
Evans	1,869,323	July 26, 1932
Friis	1,675,848	July 3, 1928
Falknor	1,698,014	Jan. 8, 1929

and also Greenleaf Whittier Pickard and E. Bruce, as well as others of whom defendant is not at present advised, but begs leave to add hereto by proper amendment to this, its answer, when such information is obtained:

(d) Because the alleged invention of the said Wheeler patent was known to others and in public use and/or on sale before the alleged invention or discovery by the said patentee or more than two years prior to his application for Letters Patent therefor as follows:

Western Electric Company, of and at New York, N. Y., at Pocono, Pa., and at East Orange, N. J.

Bell Telephone Laboratories, of and at New York, N. Y., at Pocono, Pa., and at East Orange, N. J.

E. B. Craft, of and at Hackensack, N. J.

J. J. Lyng, of and at New York, N. Y.

Greenleaf Whittier Pickard, of and at Boston, Mass.

E. Bruce, of and at New York, N. Y., and elsewhere

Howard Radio Company, of and at Chicago, Illinois,

and others of whom defendant is not at present advised,

but begs leave to add hereto by proper amendment to this, its answer, together with details thereof, when such information is obtained.

(e) Because the invention claimed in the said patent is substantially different from any invention indicated, suggested, or described in the original application therefor.

(f) Because the application for the patent in suit was filed more than two years subsequent to publication thereof and/or public use by the patentee or plaintiff in this action, or with their several or joint license.

(g) Because the alleged invention thereof was not shown and/or described in such full, clear, concise, and exact terms as to enable anyone skilled in the art to practice the alleged invention.

(h) Because the claims of the said patent cover a mere aggregation of elements.

15. Further answering the bill of complaint, defendant asserts that the state of the art before and at the time of the alleged invention and/or application for Letters Patent therefor was such that to be valid the claims of the said patent must be so narrowly construed as to be incapable of being validly applied to defendant's products.

16. Further answering the bill of complaint, defendant asserts that the said Wheeler patent is wholly void and invalid at law because of a statutory bar to the validity thereof by reason of the publication of the alleged invention thereof in the Proceedings of the Institute of Radio Engineers in January, 1928, Volume 16, No. 1.

17. Further answering the bill of complaint, defendant asserts that the said Reissue Patent No. 19,744 is invalid for each of the following additional reasons:

(a) For unreasonably failing to disclaim invalid subject matter therein contained;

(b) Because the said Reissue Patent was not applied for in conformance with the statutes pertaining to the application for reissuance of Letters Patent and that the requirements of said statutes were not complied with;

(c) That the Reissue Patent was improperly granted;

(d) That the oath which accompanied the application for said Reissue Patent was insufficient in that it did not specify the errors which it was claimed constituted the inadvertence, accident or mistake relied upon or how they arose or occurred, or any facts from which the Commissioner could ascertain whether there had been any inadvertence, accident or mistake which resulted in the insufficient claims; and

(e) That the amended and supplemental oath which was filed by the applicant during the prosecution of the application for said Reissue Letters Patent was insufficient for the same reasons as stated under paragraph (d) hereof and also because said amended and supplemental oath was false.

Wherefore, defendant denies that plaintiff is entitled to the relief prayed for, or to any relief, and prays to be hence dismissed with its costs in this cause sustained, together with such other and further relief as to the Court may seem just.

Detrola Radio and Television Corporation,
By Darby & Darby,
Its Attorneys.

Dated: New York, N. Y., March 18, 1938.

Ellmann & Rosin,
Of Counsel,
Penobscot Building,
Detroit, Michigan.

AMENDMENT TO ANSWER

(Filed June 12, 1939)

Defendant amends its answer by adding thereto the following:

"18. Further answering the bill of complaint defendant asserts that it has rights which have intervened between the date of issuance of the original patent No. 1,879,863 and the date of issuance of Reissue patent No. 19,744 in suit, which intervening rights free the defendant from any claim of infringement of said reissue patent."

Darby & Darby,
Attorneys for Defendant.
By Samuel E. Darby, Jr.

The foregoing amendment to the answer is consented to.

June 6, 1939.

Pennie, Davis, Marvin & Edmonds,
Attorneys for Plaintiff.
By R. M. Adams.

It is ordered that the foregoing amendment to the answer be made.

Arthur F. Lederle,
U. S. D. J.

Dated: June 12, 1939.

TRIAL PROCEEDINGS ON SEPARATE ISSUE

Transcript of Proceedings had in the above-entitled cause, before the Honorable Arthur F. Lederle, District Judge, at Detroit, Michigan, on Tuesday, April 11, 1939.

Appearances:

Messrs. Pennie, Davis, Marvin & Edmonds,
By William H. Davis, Esq.,
R. Morton Adams, Esq.,
Henry T. Kilburn, Esq., and

Messrs. Whittemore, Hulbert & Belknap,
By Arthur C. Beaumont, Esq.,
Appearing on behalf of the Plaintiff.

Messrs. Darby & Darby,
By Samuel E. Darby, Jr., Esq.,
Floyd H. Crews, Esq., and

Messrs. Ellman & Rosin,
By Henry P. Rosin, Esq.,
Appearing on behalf of the Defendant.

The Court: Mr. Darby, let me interrupt you here for a moment, as a matter of procedure. If you are right on this proposition of the insufficiency of the oath, that disposes of the entire controversy so far as this case is concerned, doesn't it?

Mr. Darby: Yes, sir.

Mr. Adams: It certainly would.

The Court: Well, I wonder if there isn't an obligation on the part of all of us to proceed with that issue and dispose of it and if I should happen to decide the case favorably to you on that issue, confine it to a decision on that issue, and if the plaintiff wants to have that reviewed, have that reviewed as a separate issue under the new rules. That is, in other words, at the outset it does not look like good sense to me to go through all of this entire hearing and then have the matter turn on this issue, if it is going to turn on this issue.

So I would say that there are really two steps to Mr. Darby's position there, and if I am not correct on that, you should correct me now.

Mr. Darby: That is exactly correct, your Honor.

The Court: The first is that the affidavit on its face does not show any facts from which anybody could draw the conclusion that there was accident, inadvertence or mistake.

Second, that even though the oath might—by some stretch of the imagination, he is going to say—lead some person to believe that there was a mistake, accident, and so forth, nevertheless there are facts outside of the oath that he is ready to prove, that will clearly establish to the court that there was no accident or mistake or inadvertence. And, putting in that proof, you will establish to the Court's satisfaction that the oath, although made in good faith, was not based on the situation as it actually existed, and therefore should not be considered, or, without hurting anybody's feelings or without any intention of hurting anybody's feelings, may be the short way to say is that the oath was false.

Mr. Darby: You stated it exactly, your Honor. I merely will say, for the purpose of our discussion to avoid any implication or incrimination, say "technically false."

Session of April 12, 1939

Mr. Davis: I agree with Mr. Darby that we could make a record on these issues in a very few moments, and I think it would be desirable to do it in a formal way, then if the Court rules against defendant on this issue we could start all over again, so to speak, to make the record on the other part of the case.

Mr. Darby: That is agreeable, so the two do not conflict.

The Court: Supposing you go ahead that way.

Mr. Davis: I offer in evidence an uncertified copy, by agreement, of the re-issue patent No. 19744 of October 29, 1935, granted to the plaintiff, Hazeltine Corporation, as assignee of Harold A. Wheeler, and ask that it be marked Plaintiff's Exhibit 1.

(Re-issue patent No. 19744 was thereupon marked Plaintiff's Exhibit 1.)

Mr. Davis: And we rest.

The Court: No objection? This will be received.

Mr. Darby: For the defendant, I offer in evidence an uncertified photostatic copy of the file wrapper and contents of the re-issue Wheeler patent No. 19744.

(Photostatic copy of the file wrapper and contents of Patent No. 19744 was thereupon marked Defendant's Exhibit A.)

Mr. Darby: And, Mr. Davis, will you stipulate, subject to correction if errors appear, that Judge Galston's decision, reported in 7 Fed. Supplement, 908, was rendered on August 6, 1934; the application for re-issue was filed September 26, 1934; Judge Campbell's decision, reported in 8 Federal Supplement, 100—

Mr. Davis: Well, Judge Campbell's decision hadn't anything to do with this issue, had it?

Mr. Darby: No, all right, I will strike that out. And the Court of Appeals of the Second Circuit's decision was rendered,—what was the date of that?

Mr. Davis: I have it right here. July 29, 1935.

Mr. Darby: July 29, 1935.

Mr. Adams: I would like to supplement that, Mr. Darby, by saying this; that the decree on the opinion of Judge Galston was entered September 18, 1934.

Mr. Darby: That is all right.

Mr. Adams: The appeal was taken to the Court of Appeals on September 21, 1934.

Mr. Darby: That is acceptable.

Mr. Adams: And then the application for re-issue was filed on September 26, 1934.

Mr. Darby: All right. It is stipulated that Mr. Wheeler, the patentee, testified as follows, in the case of R. C. A. Victor, Inc. and R. C. A. Manufacturing Company, Inc. vs. Hazeltine Corporation, in the U. S. District Court, District of Delaware, Equity No. 1071.

I might explain to your Honor that that was a suit for declaratory judgment.

Mr. Adams: No, it wasn't, Mr. Darby.

Mr. Darby: It wasn't?

Mr. Adams: No.

Mr. Darby: That was what I gathered from Philbin's brief.

Mr. Adams: Actually what that was, your Honor, they brought a suit to perpetuate testimony and for unfair competition. We moved to dismiss. Then, although there was some question as to the propriety under the old rules, we filed a counter-claim charging them with infringement. The other side did not protest that, and the Court took jurisdiction, and that is the way it proceeded.

Mr. Darby: He testified as follows in that case and would so admit in this case and adopt as his testimony in this case—is that right?

Mr. Davis: Yes.

Mr. Darby: I will refer to them by numbers, if you want to follow them. Page 927.

"XQ-441 Mr. Wheeler, you testified on direct examination as to your experience as a radio engineer, and have you also had experience as a patent expert in radio patent litigation?

"A. Yes.

"XQ-442 Have you testified in radio patent suits regarding patents and so-called prior art?

"A. Yes.

"XQ-443 I show you what assumes to be a copy of the record on appeal in Lester L. Jones against Freed-Eiseman Radio Corporation, which was a radio patent suit and in which in April, 1929, it appears that you testified as shown on page 944 of the printed record. Do you recall testifying in that case?

"A. Perhaps I need not check up the date on the record, but I will refer to the questions.

"The Court: Do you recall testifying in that case?

"The Witness: Yes, I do. Was the question any more than that?

"XQ-444 No.

"A. I recall testifying in that case.

"XQ-445 The first question was: 'Mr. Wheeler, will you give an outline of your experience in the radio art enough to indicate the extent of your knowledge and your ability to interpret scientific publications and follow the advances made in the industry and understand patents relating to the radio art in general.' Did you at that time understand or believe that you understood radio patents?

"A. I think so.

"XQ-446 And did you in that case act as a patent expert with respect to the patent in suit, and to various patents that were cited against the patent in suit?

"A. Yes.

"XQ-447 Do you recall testifying in the suit of Hazeltine Corporation against American Bosch Magneto Corporation in the United States District Court for the Southern District of New York in or about November, 1930, as a patent expert?

"A. I do not seem to recall this suit specifically, but if it shows up from the record, I have no doubt. I remember testifying on the subject which is involved right here at some time.

"XQ-448 That suit involved the so-called Bosch receiver. Does that refresh your recollection?

"A. I do not seem to recall this case definitely.

"The Court: Did you testify as an expert in that case?

"The Witness: That is what I do not recall, if your Honor please. I do not seem to have any definite recollection of this particular case. I do remember testifying before Judge Knox, whom it appears this case was heard before.

"XQ-449 I find on page 343 the following:

"'Will you state whether or not you are generally familiar with patents and whether or not you have followed not only the prior patents of the radio art but also the patents as they are issued by the Patent Office?

"'A. I have done that in so far as my time permitted.'

"Will you state whether or not it was true in November, 1930, that you were generally familiar with patents and had followed so far as

your time permitted, the patents as they were issued by the Patent Office?

"A. It was true.

"XQ-449A This testimony appears to show that you testified regarding various patents in that case such as the Nichols patent No. 1325879, the Rice patent No. 1334118 but you have no recollection at this time as to whether or not you did testify regarding those patents in that case?

"A. I think I did. I merely did not seem to identify this case from several others in my mind.

"XQ-450-1 Did you testify in several patent cases as a patent expert about that time?

"A. Yes.

"XQ-452 And by 'about that time', I mean in the years 1929 and 1930?

"A. I cannot recall the exact date.

"XQ-453 Or before?

"A. I am not sure about the date.

"The Court: In 1930 or 1928?

"The Witness: Several years ago is about as nearly as I can place the date of those cases in which I did testify."

Mr. Darby: This testimony was given November 17, 1936, or the day following.

Mr. Adams: The testimony you are reading?

Mr. Darby: Yes. The testimony I am reading. (Continuing:)

"XQ-454 Had you studied patents and patent claims prior to 1930?

"A. I had certainly studied quite a number of patents and I had had some experience with claims.

"The Court: Outside of the radio art?

"The Witness: No, just in radio, just in the particular part of the radio art in which I had specialized at that time."

Mr. Darby: Then page 936. (Reading:)

"XQ-489 At the time that you were doing this work on A. V. C., that is in 1925 and 1926, were you experienced in patent matters and had you read patents and studied their claims?

"A. I hesitate to characterize the amount of experience, but I had had some experience in that matter.

"XQ-490 Had you filed any patent applications prior to 1927?

"A. Yes.

"XQ-491 About how many?

"A. Very few, I think, although about that time, either just before or just after 1927, I filed quite a few applications.

"XQ-492 When you say that you filed the applications, did you mean that they were filed in your behalf by the Hazeltine Corporation?

"A. Yes.

"XQ-493 Were those applications owned by you or by the Hazeltine Corporation?

"A. By the Hazeltine Corporation."

Then page 964.

"XQ-573 You have just referred to page 85 of your notebook No. 6. I find on page 126 of the same notebook, under the heading:

"'June 23, 1926, patent and trade-mark work in line' the following reference:

"'Audiostat case (search file) "Audiostat" and "Audiostat trol"'"

"Will you tell us what that entry means?

"A. Incidentally, the last word is 'Audiotrol'.

"The Court: 'Audiotrol'?

"The Witness: Yes. That was another name

I had for the same thing. No, excuse me, that 'Audiotrol' word referred to something else. I am not sure.

"May I have the question read? (Question repeated.) That was a memorandum reminding me that in the near future we should obtain a search in the Patent Office preliminary to filing a patent application on the audiostat, and then that we should file the patent application.

"The remainder of that memorandum reads:

" 'Paper lab. work report 3 and 4 stage sets.' That referred to other work to be done on the audiostat."

Page 973 is the next one.

"XQ-611 I call your attention to a set of 22 patents relating to radio matters, in each of which you appear to be the patentee, and in each of which the attorneys are Pennie, Davis, Marvin & Edmonds, each being assigned to the Hazeltine Corporation, and the application of each being filed before 1931. Will you please state whether or not you recognize those patents as having been applied for by you, the following being a list of the numbers of the patents, the dates of the applications for the patents and the issue dates, namely.

"I will ask that this list be read into the record, and that Mr. Wheeler examine these patents later, to verify the lists."

It does not appear from the record that that question was answered, but I understand, Mr. Adams, that the answer is "Yes."

Mr. Adams: Yes.

Mr. Darby: Will you stipulate that this list appearing in that record is the correct list?

Mr. Adams: Yes.

Mr. Darby: May I ask to have this list copied into the record?

List of Wheeler Patents Applied for Before 1931

No.	Application Filed	Issued
1,757,494	February 27, 1925	May 6, 1930.
1,844,374	August 20, 1930	February 9, 1932.
1,846,701	May 28, 1930	February 23, 1932.
1,855,619	January 20, 1928	April 26, 1932.
1,866,687	December 8, 1927	July 12, 1932.
1,868,155	June 20, 1929	July 19, 1932.
1,873,~~926~~236	September 22, 1928	August 23, 1932.
1,878,653	August 20, 1930	September 20, 1932.
1,878,740	July 16, 1929	September 20, 1932.
1,878,741	August 17, 1929	September 20, 1932.
1,878,742	August 17, 1929	September 20, 1932.
1,878,743	August 17, 1929	September 20, 1932.
1,879,861	November 10, 1930	September 27, 1932.
1,879,862	November 10, 1930	September 27, 1932.
1,879,863	November 13, 1930	September 27, 1932.
1,895,091	August 19, 1930	January 24, 1933.
1,896,500	September 22, 1924	February 7, 1933.
1,904,185	February 17, 1927	April 18, 1933.
1,907.916	August 19, 1930	May 9, 1933.
1,910,870	September 10, 1930	May 23, 1933.
1,927,672	September 10, 1930	September 19, 1933.
1,943,405	September 10, 1930	January 16, 1934.

The Court: Just in passing, Mr. Darby, how many patents are there?

Mr. Darby: 22 patents.

The Court: 22.

Mr. Darby: Beginning with applications filed in 1925, and the latest one filed was some time in 1930, as far as I can see by running over the list hurriedly.

22 patents, the latest of which was filed in 1930.

I also offer in evidence certified copy of the file wrapper of the original patent as Defendant's Exhibit B.

Mr. Davis: Well, what has that to do with this issue?

Mr. Darby: It shows the orderly prosecution of the application for the original patent, shows the absolute absence of inadvertance, accident or mistake in the procurement of the original patent.

Mr. Davis: I object to that in this branch of the case. I can't see any relevancy.

The Court: You are objecting on the ground that it is immaterial?

Mr. Davis: Yes, your Honor.

The Court: Overruled. Received.

(The certified copy of file wrapper of original patent was thereupon marked Defendant's Exhibit B.)

Mr. Darby: The defendant rests on this defense.

Mr. Davis: You are through?

Mr. Darby: Yes.

Mr. Davis: Then the defendant rests on that issue, and the plaintiff rests on that issue.

The Court: I do think, however, that you ought to have in the record something more about Wheeler's connection with the Hazeltine Company and the Hazeltine Company's connection with his patent.

I wonder if that shouldn't be added, Mr. Darby.

Mr. Darby: Yes, your Honor made the suggestion. It really was an oversight on my part.

Mr. Davis (Interposing): My suggestion is we put Mr. Wheeler on the stand and let him tell the story in his own words. I am going to ask Mr. Adams to examine the witness.

The Court: All right.

Mr. Adams: Mr. Wheeler.

HAROLD A. WHEELER, was thereupon called as a witness on behalf of the Plaintiff, and having been first duly sworn, testified as follows:

Direct Examination

By Mr. Adams:

Q. Are you the Harold A. Wheeler of the re-issue patent here in suit?

A. I am.

Q. What is your present connection with the Hazeltine Corporation, Mr. Wheeler?

A. The Hazeltine Corporation—

The Court: Will you stand over there, Mr. Adams, then he will talk loud enough so that you can hear, and also Mr. Darby.

A. The Hazeltine Corporation has an organization known as the Hazeltine Research Corporation which conducts—

Q. (Interposing): Hazeltine Service?

A. Hazeltine Service Corporation, which conducts its engineering work; and I am Vice President and Chief Consulting Engineer of the Hazeltine Service Corporation.

Q. What sort of work does that corporation do?

A. We do engineering work, partly developing improvements in radio apparatus; now we are working largely on television improvements; and partly cooperating with manufacturers who are making radio receiving apparatus in various parts of the country.

We have to this end three different laboratories established. The head laboratory is in New York City, the city proper, and that laboratory does consulting work directly for radio manufacturers.

We have another laboratory which has been until recently in Bayside, New York, on Long Island, but which

is just now occupying a new building in Little Neck on Long Island. I spend most of my time at that laboratory, where we specialize in advance developments; as I say, mostly in television at the present time.

The third laboratory is a branch laboratory in Chicago for the assistance of manufacturers who are located in that neighborhood.

Q. In what way do you cooperate with these manufacturers?

A. In two respects. We have our own developments which we are anxious to have them use, and which we describe to them and make every effort to assist them in using in their own receivers. Then when these manufacturers have special problems, or have receivers which they wish to have tested, they come to us for information and for testing the receivers. We have one of the best equipped laboratories for testing radio and television apparatus.

Q. Do you help them design receivers?

A. Yes, we do.

Q. Do you help them with their manufacturing problems?

A. Yes.

Q. Are they licensed under the Hazeltine Corporation patents?

A. Yes.

Q. What does the corporation do about securing patents? What is their practice?

A. We have now and have in the past always had attorneys who were retained for the purpose of filing our patent applications. We are active in making new developments and in filing patent applications covering these developments through these attorneys.

Q. When you yourself make inventions do you assign them to the corporation?

A. Yes.

Q. And does the corporation then have the application for patents filed?

A. Yes.

Q. Has that always been true during your relationship with the Hazeltine Corporation?

A. For the most part it has. There were some exceptions at some times in the past.

Q. When did you first become connected with the Hazeltine Corporation?

A. At the time it was founded, early in 1924.

Q. Had you at that time made this invention which forms the subject matter of the re-issue patent here in suit?

A. No, I had not.

Q. What was the circumstance under which you became connected with the Hazeltine Corporation?

A. I had made another invention relating to radio receivers, which later became known as the neutrodyne receivers. I found through accidental contact with Professor Hazeltine that he had independently made the same invention earlier than I had, but that immediately established a bond of mutual interest between us. From that time on I was first closely associated with Professor Hazeltine in his work and then when the Hazeltine Corporation was formed early in 1924 I was retained by the corporation for working as much time as I could spare outside of my school work. Then when I finished my school work I continued full time work in the corporation's laboratories.

Q. How old were you then, Mr. Wheeler?

A. In 1924 I was 21.

Q. Where were you in school?

A. I was then attending George Washington University in Washington, D. C., in the Physics Department.

Q. And when you graduated from there where did you go?

A. In 1925 to 1928 I attended Johns Hopkins University, in their Graduate School of Physics.

Q. During that time were you associated with the Hazeltine Corporation?

A. Yes, I spent summers and a good deal of time during the school year visiting their laboratories, or working on their problems.

Q. Where was their laboratory at that time?

A. At Hoboken, New Jersey.

Q. Where in Hoboken?

A. It was in some space in one of the buildings occupied by the Stevens Institute of Technology, where Professor Hazeltine had been connected.

Q. Was that the only laboratory they had at that time?

A. Yes, it was.

Q. Now, at that time, was it at about that time that you became interested in the subject of blasting and which led to the making of this invention which forms the subject matter of the patent here in suit?

A. Yes, about 1925.

Q. Will you tell us the circumstances?

A. In the summer of 1925, as usual I went to the laboratory for the summer's work. Radio receivers were being improved very rapidly then with regard to the amount of amplification which could be obtained in the receiver. On arriving at the laboratory I was operating some of the more recently developed receivers which they had there, and I was struck with a problem which had not occurred to me previously. That was the problem of blasting while tuning from one station to another. The receiver had so much amplification that one of the principal operations the user had to perform

when he was operating the set was to reduce the amplification to the amount which was needed for the signal he wished to receive.

Q. Well, tell us, or have you explained fully what this phenomenon of blasting is?

A. "Blasting" is our word which means the loud and distorted signals which you sometimes get when tuning from one station to another before the receiver is properly adjusted. That is, we may be originally tuned in on a fairly weak signal, so we have the amplification in the receiver turned up to as much amplification as we can get. Then we decide to tune to another station, a local station which sends out a much stronger signal. As we tune into the local station then, the amplification of the receiver is too much. That makes the sound too loud; in fact, so loud that it is distorted in the receiver and is harsh.

It is then the problem of the operator to turn down the amount of amplification to the amount required by the relatively strong signal. The loud reproduction is what we call "blasting", and the control which the user operates to reduce the amplification is the control which we commonly call the volume control.

Q. Well, did you try to devise some radio system that would eliminate that defect?

A. Yes.

Q. Did you in the course of that work devise various schemes to that end?

A. Yes, I spent a great deal of time and attention on that problem from the middle of 1935 until the end of 1935.

The Court: Do you mean '35, witness?

A. Excuse me. 1925.

Mr. Adams: Now, I may say, your Honor, that the work that Mr. Wheeler did during that interim will

become interesting and important in later phases and other phases of the case, but I am not going to go into at this time.

The Court: All right.

Q. (By Mr. Adams): Did you finally devise a radio receiver which did solve this particular problem to your satisfaction?

A. Yes.

Q. When was that?

A. In the Christmas holidays of 1925 to 1926. That is, in the latter part of December, 1935.

Q. 1925.

A. 1925.

Q. Will you tell us just briefly about that receiver, what kind of a receiver it was, what it was composed of?

A. This was a receiver of the type which is called a super-heterodyne, one which had been invented some years before by Major Armstrong but which was not most commonly used at that time; that is, in 1925. I made this super-heterodyne receiver with a number of amplifying stages so there were a total of eight tubes in the receiver.

The first new amplifying stages of the receiver were used to amplify the signal at carrier frequency or at radio frequencies before it was subjected to the process of detection. Then I had one vacuum tube used as the detector, a vacuum tube of the diode type, which actually I obtained by connecting one of the ordinary triode tubes in the manner of a diode. Then the last two tubes of the receiver were used to amplify the signal at the sound or audio-frequencies after being detected. The unusual features of that receiver centered around the detector and the improvement which I called "automatic volume control." The detector itself, the diode and its immediately associated connections, were of a type which I

had devised especially for this receiver. The diode was arranged so that it performed not only the essential process of detection of the signal, but also provided a rectified potential which could be used for automatic volume control, and I did connect this rectified potential back to the amplifier in such a way that stronger signals, just by their reception and amplification in the receiver, caused the amplification to be reduced to just the amount required for the stronger signals.

Q. Was that invention or development, that system of yours, embodied in any other receiver at about that time?

A. Shortly after I made this Washington receiver (this receiver to which I have referred was made at my home in Washington, D. C.), that is, in August of 1926, the same arrangement was constructed under my supervision in a commercial receiver of the Stromberg-Carlson Company.

Q. Did you advise the Hazeltine Corporation of this invention and did they at some time after file an application for patent on it?

A. Yes.

Q. Now, was this system that you had embodied in these receivers described and disclosed in the specifications of that patent application?

A. Yes.

Q. Now, there are here two receivers, Mr. Wheeler. Is one of them this Washington receiver to which you have referred?

A. This large model on top of the table is the Washington receiver.

Q. Now, then, is the so-called Stromberg-Carlson receiver here also?

A. Yes, the large cabinet on the floor is the Stromberg receiver.

Mr. Adams: I would like to offer them in evidence at this time.

The Court: All right, they may be received and then we will excuse you until tomorrow morning.

(The Washington receiver above-referred to was thereupon marked as Plaintiff's Exhibit No. 19.

The Stromberg-Carlson receiver above-referred to was thereupon marked as Plaintiff's Exhibit No. 14.)

(The hearing was thereupon adjourned to Thursday, April 13, 1939, at 9:30 o'clock a. m.)

Detroit, Michigan.
Thursday, April 13, 1939.
9:30 o'clock A. M.

Court convened pursuant to recess.

Parties present the same as before.

The Court: All right, Mr. Davis, you may proceed.

Mr. Davis: Mr. Adams will continue.

Mr. Adams: Mr. Wheeler.

HAROLD A. WHEELER, thereupon resumed the stand as a witness on behalf of the Plaintiff, and having been previously duly sworn, testified further as follows:

Direct Examination
(Continued)

By Mr. Adams:

Mr. Adams: Yesterday just before we closed, Mr. Wheeler had said an application had been filed, and he identified the radio receiving sets which he had built which embodied his automatic volume control system. I would now like to ask Mr. Wheeler just what he did toward filing that patent application.

A. After the Stromberg receiver was completed and was demonstrated in the laboratories in Hoboken, I talked

with Mr. MacDonald, the chief engineer, and we decided that a patent application should be filed on this improvement as soon as it could be prepared. At that time I was returning for the winter session at Johns Hopkins, and so I got together the information for the patent application in Baltimore.

Q. What sort of information?

A. I prepared sketches which were later copied and became the drawings of the application.

Q. When you say "sketches", were they circuit diagrams?

A. Yes, I prepared circuit diagrams corresponding to the two receivers we have mentioned, and some additional diagrams showing other variations. Figures 1 and 3 of the application were the diagrams corresponding to these two receivers. Also I prepared a brief description of the system which I sent along with the sketches to our patent attorneys, that is the office of Pennie, Davis, Marvin & Edmonds.

The Court: What year was that, again?

A. This was in the fall of 1926.

Q. (By Mr. Adams): Did the Hazeltine Corporation at that time have any resident patent attorneys of its own?

A. No, we relied entirely on this firm.

Q. Well, what does it do now?

A. Now we have grown to the point where we have patent attorneys located at the New York laboratory. We have three men who spend practically all of their time filing the patent applications of our engineers.

Mr. Adams: And I may say, your Honor, that our firm now is retained only for purposes of litigation.

Q. (By Mr. Adams, continuing): Well, now, at that time when you submitted this information for the purposes of a patent application, were you the one who dealt with the solicitor, the patent solicitor?

A. Yes.

Q. Did anybody else in the Hazeltine Corporation have anything to do with that?

A. Not after we decided to file the application.

Q. Tell me just what happened after that, which was in the fall of 1926.

A. After I submitted the description to the attorneys, one of their men was assigned to the preparation of the application and I dealt with him in the preparation of the application. By that I mean I was in Baltimore most of the time, but I exchanged correspondence, and every month or two I made a trip to New York and would call on the attorneys to explain to them anything that had come up in the preparation of this application.

Q. Was a formal application finally submitted to you for signature?

A. Yes, in the spring of 1927.

Q. Did you examine that application at the time to determine whether the invention of these receivers was disclosed in the application?

A. I did.

Q. Was it so disclosed?

A. Yes.

Q. Were the circuits contained in the applications?

A. Yes.

Q. Was there a description of the system?

A. Yes, there was.

Q. And were the values of the important parts given?

A. You mean by "important" the unusual parts that had been added for this improvement?

Q. Yes.

A. And all the necessary elements which were at all different from ordinary receivers?

Q. Yes.

A. Those were all described thoroughly, and the values given.

Q. Did you satisfy yourself at that time that the description was such that any person skilled in the radio art could have duplicated the system that you had devised and which was in these two receivers that you have identified?

A. Yes.

Q. And it was so disclosed?

A. Yes.

Q. Did you then execute the application?

A. Yes.

Q. What happened after that?

A. This particular application was then in the hands of Mr. Guild of your office, and there was some lapse of time after the application was filed before he heard from the Patent Office, but whenever the Patent Office would communicate any objections to our patent attorneys, Mr. Guild would get in touch with me and would ask me questions about the technical features of their objections. For example, they cited patents which had already been published, and I would explain to him all the differences between the systems in these patents and the systems described in my application.

Q. When you say that you would describe it to him, do you mean you would point out to him the differences that existed between yours?

A. Yes.

Q. And these others?

A. Yes.

Q. Were those differences differences that had been disclosed in the application as originally filed?

A. Yes.

Q. Did this happen a number of times during the course of the prosecution of the application?

A. Yes.

Q. Did you yourself draw the claims?

A. No.

Q. What did you have to do with that?

A. The application as originally filed, I merely looked over the claims that had been prepared by the attorneys to see if they seemed to be technically accurate and reasonably descriptive of the apparatus. I did not pay very much attention to the claims in the application at first. When the objections were raised, Mr. Guild would ask me questions about the claims too, as to whether they were accurately descriptive of our apparatus, of our system, and in some cases whether the description of some parts of the claims would apply to the references, the patents that had been cited by the Patent Office.

Q. When you would point out these differences between your device and the other devices, would you then leave it to Mr. Guild to embody those differences in claims?

A. Yes.

Q. Now then, when the patent was finally granted, did you then examine, or did you then look it over?

A. Yes.

Q. Did it at that time disclose the system which you had embodied in these devices?

A. Yes, the description was not changed in any important respect; that is, the description was still the same as when we had filed the application, and that was entirely accurate.

Q. Now, I think that was sometime in 1932. Yes, that was granted September 27, 1932. During this time of the prosecution of the application, had you ever seen the Affel Patent No. 1,574,780?

A. No.

Q. When did you first see that patent?

A. Some time after the patent was issued; I mean some time after my patent was issued; we were preparing for some litigation in Brooklyn and this patent was then called to my attention, among others which had to be considered in that litigation.

Q. One thing I would like to have you do, I notice that your Honor looked at these sets and perhaps it might be a little clearer if Mr. Wheeler just pointed out something about these sets to your Honor so that you can see and understand the physical nature of what he invented.

The Court: All right.

Mr. Darby: I take it from the fact that your Honor did examine them that you are interested in them. Of course that is not relevant to our present inquiry.

The Court: It may not be. I do not think it will take very long.

Mr. Darby: I won't make any objection.

The Court: Mr. Wheeler, will you talk loud enough so that the reporter may hear you?

A. Yes. The receiver has here seven small boards on which are mounted all the apparatus except a few parts connected outside these boards. The first five boards, starting from the left, contain apparatus which is essential in any super-heterodyne receiver. Each board contains one tube and its associated circuits. These tubes are used for amplifying and for another process which is essential in a super-heterodyne receiver, but which is incidental to securing its large amount of amplification.

On the sixth board from the left is the detector or rectifier tube. The tube itself is an ordinary triode tube of the old style which was then in use, mounted in a socket, and the socket has two of its terminals connected together by a wire around the base of the socket.

Those two terminals are the grid and p .te terminals of the triode tube, and that is the arrangement I used to secure in effect a diode tube, since only the triode type of tube was handy at that time.

These two terminals connected together then formed the anode terminal of the diode, in effect. There is connected with this diode arrangement a high resistance for developing the rectified potential out from the diode. That high resistance is one of the two tubular units mounted in clips just in front of the diode detector tube. It is the righthand one of these two tubular resistors. It is connected by wires between the anode terminal and one of the remaining two terminals on the sockets.

The remaining terminals are the filament terminals because this type of tube had a filament used as the cathode.

So that is the way this resistor was connected between the anode and cathode terminals of the diode; or those terminals of the triode connected as a diode.

Then the rectified potential developed across that resistor was connected back to one of the amplifier tubes in order to furnish an automatic control of its amount of amplification. I can follow this connection through the circuit by describing the elements in succession, from the anode of the diode back to the amplifier tube.

The anode of the diode is connected through the left-hand one of the two tubular units I referred to in front of the detector tube. Then there is a wire that goes to the left clip from the front of the same board. That is connected to a clip on the left-hand side of the last board on the right. From there it goes to another tubular resistor on the front of the last board, the right-hand board.

Then there is a long wire in front of all of the boards which goes back to the left-hand front clip on the third

board from the left. Then there is a wire going to the back part of that board through another tubular resistor mounted in a clip. And that wire goes back to the grid terminal of the amplifier tube mounted on that third board. It is this connection through which the rectified potential was delivered from the detector or rectifier tube back to the amplifier grid for automatic control of the amount of amplification, to obtain the result which we called automatic volume control.

Q. You referred, Mr. Wheeler, to the first five boards being, as I understand it, important in a super-heterodyne. Was that part of the device the same in the Washington receiver, Exhibit 19, as it was in the Stromberg-Carlson receiver, Exhibit 14?

A. No, the principal difference between these two receivers was that the Stromberg receiver did not employ the super-heterodyne type of circuit. It employed the circuit which was in more common commercial use at that time, which we called a t.r.f. circuit, a tuned radio frequency amplifier. This difference was merely a difference in the method of amplifying the modulated carrier signal before detection.

The Court: Just a minute.

(Interruption.)

Q. Had you finished?

A. Yes.

Q. Which of these two forms of amplifiers is disclosed in your patent?

A. The t.r.f. form as used in the Stromberg receiver.

Q. Is the super-heterodyne form disclosed there?

A. It is not shown in the diagrams but it is mentioned in the text.

Q. And was that a well-known form—

A. Yes.

Q. —of amplifier at that time?

A. Yes.

Q. There was one thing that I find that I had intended to ask you and didn't; in connection with the prosecution of patent applications on the part of the Hazeltine Corporation do they have at the present time a number of patents that they own?

A. Yes, we own about 200 patents I think at the present time.

Q. Do you participate in the prosecution of the applications for the patents at the present time?

A. Very seldom, except for those that are filed in my name; that is, just occasionally I am called in to have some consultation on the others, but that is the exception rather than the rule.

Q. I assume from what you said that all of these 200 patents are not on your inventions?

A. Oh, no.

Q. And the applications which are filed at the present time by the Hazeltine Corporation are on inventions made by other people than yourself?

A. Oh, yes.

Q. Do you know what the practice is as to how those applications are communicated to the attorneys and how they prosecute the applications? Tell us something about that.

A. The engineers communicate the description of their developments directly to the patent attorneys. Then Mr. MacDonald, the vice-president in charge of engineering, passes on what applications are to be filed, and the attorneys consult the engineers directly for any information they need to have in preparing the application.

Q. During the course of the prosecution, what do the attorneys do?

A. Any information they need they get directly from the engineers.

Q. What sort of information do you have in mind?

A. Whenever any objections are raised by the Patent Office, it is customary for the attorney to consult the engineer in whose name the application is filed, to have him point out the differences between his arrangement and the arrangement shown in the patent cited by the Patent Office.

Mr. Adams: That is all.

Cross Examination

By Mr. Darby:

Q. Mr. Wheeler, as I understand it, the Hazeltine Corporation was formed in February, 1924, is that correct?

A. Approximately; I think it was about the end of March.

Q. And it was formed to take over the inventions and patent rights of Professor Hazeltine?

A. Yes.

Q. And you became associated with it about 1925, or was it about the same time?

A. Immediately.

Q. Immediately?

A. Yes.

Q. And you have been associated with it continuously ever since?

A. Yes.

Q. And the Hazeltine Corporation is not a manufacturing concern, is it?

A. No.

Q. It owns patent rights and its source of income is royalties it receives under licenses it grants to manufacturers under those patent rights, is that right?

A. Yes.

Q. And you stated, I think—

The Court: Mr. Darby, I think the witness said earlier that was part of the income; the rest of the income he got acting as consultant for manufacturers.

A. No, that is almost entirely our source of income. Our engineering work is something which we furnish to the extent that we can to the manufacturers.

The Court: It is a service going along with your patents?

A. Yes, sir.

The Court: I see.

Q. (By Mr. Darby): It is part of the license agreement?

Mr. Adams: No, I think that is not so, Mr. Darby, it is not actually a part of the license agreement, it is a service they render independently.

Q. All right. You do not render that service to anyone other than your licensees, do you?

A. As a rule we do not; there are just a few exceptions.

Q. I think you stated at the present time Hazeltine Corporation has something in the neighborhood of 200 patents.

A. Yes.

Q. And do you recall approximately how many Hazeltine Corporation had at the time of the trial of that case in Brooklyn, Mr. Binns I think testified approximately 157; would that be approximately right in your belief?

A. Yes.

Q. And this research department, you are the head of the research department, are you not, of Hazeltine?

A. For a time I was in direct supervision of the research work. That was in 1930 to 1936. But, at the present time the research work is directly under the supervision of another engineer, but I have very close connection with it.

Q. Included in the work of the research department was to make and develop new inventions so as to build up your patent position, was it not?

A. Yes.

Q. And you of course knew throughout that time, or since 1924 when you first went with the company, the function or the purpose of the claim of a patent, didn't you; it was the claim that defined the monopoly of the patent?

A. Well, I have never had a very clear view of just what the function of the claim was. In fact, I am still—my views are still changing from time to time. I have thought I knew at times.

Q. You know that the claim had to accurately describe the invention, didn't you?

A. Well, I should think—I have thought that was the intention and still the language used in the claim sometimes mystified me.

Q. True, but you knew that was the intention of the claims, was to define the invention?

A. I think so.

Q. And you likewise knew, or were advised by your patent counsel, that to determine whether or not there was an infringement of your patent it was the claim of the patent that had to be violated?

A. I certainly knew the claims were involved, but they have told me also that the claims, not only the claim but also the disclosure in the text was pertinent to questions of infringement.

Q. By the way, who is Mr. Binns?

A. He is the treasurer of the Hazeltine Corporation.

Q. And Mr. Binns testified in the Emerson case that approximately $100,000 a year is expended by the Hazeltine Corporation in the maintenance of its research department laboratories, is that correct to your knowledge?

A. Yes.

Q. Now with respect to your practice of retaining attorneys. As I understand you, the firm of Pennie, Davis, Marvin & Edmonds were the attorneys of the Hazeltine Corporation at the time it was organized?

A. Yes.

Q. And have been continuously ever since, with rare exceptions that you mentioned?

A. Well, there was one definite change of status in the meantime. For quite a number of years this firm filed all of our patent applications for us, and also conducted litigation, but during the past few years this firm has been retained only for purposes of litigation and we have had our own attorneys for filing applications.

Q. So I understand. That is, you set up your own resident attorneys?

A. Yes.

Q. And that was comparatively recently, wasn't it?

A. Yes, just I think about three years ago.

Q. About three years ago, and up to that time Pennie, Davis, Marvin & Edmonds handled all of your patent applications, as well as your other patent work, except for the few exceptions you referred to?

A. Yes.

Q. And at that time you knew that the firm was exceptionally experienced in radio matters, did you not?

A. Yes.

Q. As a matter of fact, they had a number of men either in that firm or employed in that firm that devoted their time almost exclusively to radio matters, did they?

A. Yes.

Q. And did they have what you knew as a radio section, men who did nothing but radio work?

A. Yes.

Q. Mr. Guild to whom you referred was the head of that section?

A. I am not sure. I don't think he was.

Q. But he was a member of that section?

A. Yes.

Q. And I think you stated that the specifications and the claims that had been prepared by Mr. Guild were referred to you when they were prepared, prior to execution?

A. Yes.

Q. And you read over the specifications and claims to make sure that they were accurate?

A. Yes.

Q. And had correctly described your invention?

A. Yes.

Q. And then you executed your application and filed it, is that right?

A. Yes.

Q. And thereafter throughout the prosecution of the application you kept in more or less constant touch with the progress of the application through the Patent Office?

A. Yes.

Q. And then at some time during the prosecution of the application, the application was allowed, is that right?

A. Yes.

Q. And during that prosecution when the claims were being rejected because of prior references, you analyzed those references with reference to the grounds of rejection and with reference to your claims and helped in every way you could in overcoming those references, is that right?

A. Yes.

Q. And it was not until after the patent issued that you had called to your attention a patent to Affel, No. 1,574,780, is that right?

A. Yes.

Q. You said it was called to your attention first in connection with the preparation for this trial in Brooklyn; you referred to the trial against the Emerson people, did you not?

A. Yes. I am not sure—we had two trials, as you know, about the same time in Brooklyn.

Q. Emerson or R. E. B.?

A. Yes, it was one of those cases.

Q. I don't know which one preceded the other myself at the present time, but I note from the printed record on appeal in the Emerson case that the Affel patent was set up in an answer dated May 24, 1934, and I wonder if that would help you fix the date, the approximate time this patent was called to your attention; would you say that was about the time?

A. I think so, Mr. Darby.

Q. May, 1934?

A. Yes.

Q. And of course after the application was prosecuted through to allowance, you were advised that the application had been allowed?

A. Yes.

Q. By the Patent Office?

A. Yes.

Q. And before the patent was issued, you reviewed the application and claims before you authorized the radio section of Pennie, Davis, Marvin & Edmonds to issue the patent, is that right?

A. Yes.

Q. And as a matter of fact that was the standard practice of Hazeltine Corporation?

A. Yes.

Q. And still is?

A. Yes.

Q. To review the specifications and claims and make sure that they are proper and acceptable?

A. That is correct.

Mr. Darby: That is all.

Re-Direct Examination

By Mr. Adams:

Q. I have one question, Mr. Wheeler. When you were considering these references that had been cited by the Patent Office that had been called to your attention by Mr. Guild, these references on which the claims had been rejected, in what way did you try to help Mr. Guild in that particular kind of a matter?

A. I read over each patent that had been cited, and tried to tell him how the system worked which was described in each patent, and then to point out the differences between that system and the system described in our application.

Q. I understood you to say a moment ago that in that connection you considered the claims which had been rejected. From what point of view did you consider the claims?

A. Well, there were some things mentioned in the claims and Mr. Guild would ask me, could some element like that be said to exist in these prior applications, and whether it was a proper description of our apparatus as far as the technical operation was concerned; I tried to help him in every way I could to understand the language of the art and to use this language correctly.

Q. To what end?

A. So he could draw up claims which were expressed in the proper language and he had the right terms describing the right pieces of apparatus.

Q. I know, but what purpose did you have in your mind to accomplish by doing that?

A. I wanted him to get us a patent which would secure for us whatever protection our development was entitled to.

Q. And at the time the patent was allowed and it was submitted to you and you examined the specifications and the claims, from what point of view did you examine it then?

A. Mostly from the angle of having the description of the system complete and accurate in the text of the specification. Also, I always read over the claims to be sure that there were no errors of the description in the claims.

Q. What do you mean by "errors of the description"?

A. Patent attorneys frequently fail to understand the terms we use in a complicated art like radio, and one of our problems in getting patent applications filed is to explain to the attorneys how our terms are used, and to be sure that they don't use them with a different meaning from the accepted meaning.

Mr. Adams: That is all.

Re-Cross Examination

By Mr. Darby:

Q. Just one question, Mr. Wheeler. I think you stated in cross examination bearing on this point that at the time you put this application in the hands of Pennie, Davis, Marvin & Edmonds, you knew at that time they had had a vast amount of experience in radio patent matters?

A. Yes, Mr. Darby.

Mr. Adams: What do you mean by "vast"?

Mr. Darby: Well, the witness knew what I meant.

Q. (By Mr. Darby): And they had conducted to your knowledge numerous litigation involving radio patents?

A. I didn't know very much about those, but of course I did hear about incidents now and then that had been in those litigations.

Q. Yes. At that time you knew that they had represented Major Armstrong in the famous DeForest-Armstrong controversies?

A. Yes.

Q. And at that time you were 21, I think you said?

A. In 1924 I was.

Q. Yes. Did you believe that Pennie, Davis, Marvin & Edmonds were familiar with the nomenclature of the art at that time, at least as familiar as you were at 21?

A. No.

Q. How is that?

A. No, they had been dealing with some particular systems in radio and they had developed what they considered satisfactory terms for those systems, but then each of my applications would generally introduce some new kind of operation that they were not familiar with, and sometimes I had great difficulty in getting them to describe it accurately.

Q. I see. But they—

A. (Interrupting): In general—

Q. (Interrupting): That relates to your new ideas?

A. Yes.

Q. But in general, the nomenclature of the general art, they were thoroughly versed in, to your knowledge?

A. That is correct.

Mr. Darby: All right, that is all.

Mr. Adams: That is all.

Mr. Davis: That is all.

Mr. Adams: Step down.

(Witness excused.)

Mr. Davis: If your Honor please, I wonder if Mr. Darby would stipulate that if Mr. Baldwin Guild were

called here, he would corroborate Mr. Wheeler's testimony as to the relations between them, and would testify that he did co-operate, as is evidenced by the file wrapper, with Mr. Wheeler in the preparation and the prosecution of this patent application, and in the endeavor to define the invention and differentiate it from what was previously known in the claims, and that in doing so he consulted Mr. Wheeler, as Mr. Wheeler has testified, with respect to the disclosures of the prior patents, with respect to technical matters and included in that discussion the language of the claims, which I think Mr. Darby would bring out on cross-examination.

Mr. Darby: If you think such a stipulation is necessary, Mr. Davis.

The Court: What, in effect, Mr. Davis asked at the outset was whether you would concede that if Mr. Guild were called, that he would testify in a manner to corroborate the testimony of Mr. Wheeler in so far as Mr. Wheeler's testimony related to his relationship to Mr. Guild in connection with this patent application and prosecution.

Mr. Darby: Surely, if he wants the stipulation as he outlined it, I certainly would so stipulate.

I would like to have it agreed, what I understand is the fact, that Mr. Guild is an electrical engineer as well as an attorney. I understand that is the fact.

Mr. Davis: That is a fact. He had technical training in school.

Mr. Darby: If Mr. Davis wants that, I have no objection to it.

The Court: All right.

Mr. Davis: I am informed Mr. Guild at college studied electrical engineering, he did not graduate, and he never practiced electrical engineering.

Mr. Darby: I accept your statement, Mr. Davis, al-

though that does not correspond with what I am informed.

Mr. Davis: Then I suggest that we leave his Honor's statement as it is.

The Court: All right.

Mr. Davis: That would complete the proof, your Honor, and I understand there is nothing further?

Mr. Darby: No.

The parties thereupon on April 13, 1939 submitted to the Court Proposed Findings of Fact agreed to by both parties and the Court on April 17, 1939 so found the facts and filed them with its conclusions of law overruling these defenses. Said Findings of Fact and Conclusions of Law are printed herein at pages 838 to 846.

Thereafter, on October 25, 1939, the Court resumed hearings on the other issues and the following proceedings were had:

TRIAL PROCEEDINGS ON THE OTHER ISSUES

Session of October 25, 1939

HAROLD A. WHEELER, was thereupon called as a witness for and in behalf of the Plaintiff, and being first duly sworn, testified as follows:

Direct Examination

By Mr. Adams:

Mr. Adams: When Mr. Wheeler testified before, your Honor, he told of his connection with the Hazeltine Corporation and his present duties with them, how he first became associated with them.

The Court: I recall he started out as a student and then he became acquainted with Professor Hazeltine, and they became interested in one another, and finally got together.

Mr. Adams: At that time there was no reason for identifying Mr. Wheeler in the radio art.

The Court: Yes.

Mr. Adams: And I think it would be appropriate at this time to ask him what his activities are generally in the radio art.

The Court: All right.

Q. (By Mr. Adams): Will you tell us that, Mr. Wheeler?

A. Yes. Outside of my employment with the Hazeltine Service Corporation I have been active in the technical societies, notably the Institute of Radio Engineers. I happen to hold the fellow grade of membership in the Institute of Radio Engineers, which is an honorary grade, and also I have served as a director of that institute. The activities of the Institute include a great deal of committee work, whose purpose is to further the interests of all the members by a mutual understanding in technical matters.

I have been active in the committee work, and especially as chairman of their radio receivers committee from 1932 to 1937. This is the committee in which selected members of the Institute get together and arrive at an agreement as to the methods of testing radio receiving apparatus, and also they try to agree on terms that are to be used in talking about the apparatus.

Several reports of that committee were issued during my chairmanship. In addition to the committee work, of course, the Institute of Radio Engineers holds periodic meetings and conventions for the dissemination of technical information among their members. I have presented numerous papers before these meetings. I have attended the meetings frequently and in every way I have tried to keep abreast of radio developments.

Q. Now, I have forgotten whether you told us before,

—will you just tell us for a moment when it was you first became interested in radio?

A. In 1916 when we moved from the West to Washington, D. C., was when my interest in radio started. I didn't have any apparatus for a few years, but in 1918 I obtained a commercial operator's license. In 1920 to 1922 I operated an amateur receiving and transmitting station of my own, and during this period I tried to learn all I could about radio, outside of my school work, which was then in the elementary stages.

The only prior employment I had was as a laboratory assistant in the Bureau of Standards radio laboratory in the summers of 1921 and 1922, and part time during the intervening winter.

Mr. Adams: Now, with that preliminary statement, your Honor, we may pick up the testimony that we omitted at the previous hearing. Mr. Wheeler identified his set as the culmination of his work, but he did not then refer to the actual work which led up to it, and which is in his notebooks.

Q. (By Mr. Adams): Now I show you a notebook, Mr. Wheeler, and ask you to identify that. (To the Court): There is a copy of the pages to which he will refer.

A. This notebook, marked "Notebook No. 6, July 3, 1925, to July 1, 1926," is the laboratory notebook in which I recorded matters of interest to my employer, the Hazeltine Corporation, during that period of time.

Q. What was your practice in keeping notebooks, Mr. Wheeler?

A. Ever since I was operating an amateur station I have kept a notebook recording technical data about the apparatus I was using, and anything else which I thought was of interest in connection with it.

Q. Was that kept chronologically?

A. Yes.

Q. The subject matter was discussed from time to time with other people that might be interested in it?

A. Yes.

Q. And did they from time to time sign it to show that they had seen it?

A. Yes.

Q. Now, what is the first entry in this notebook that refers to this matter of automatic volume control?

A. On page 14, under date of July 9, 1925, in the middle of the page, is an entry entitled "Loud speaker volume control."

Q. Now, what was the circumstance of that entry?

A. Just a few days before that date I had arrived at the laboratory, the Hazeltine Laboratory, which was then located in one of the engineering buildings of the Stevens Institute of Technology, for the purpose of summer work, and shortly after arriving at the laboratory I was operating their receivers of recent development, and it was then that I first appreciated that automatic volume control could be obtained, and started to work on apparatus,—or started to devise arrangements for doing that.

Q. What was there about the apparatus that led you to devote yourself to that problem?

A. The difficulty with the apparatus which struck me was the problem of blasting.

Q. What do you mean by blasting?

A. By blasting we mean the loud and harsh sounds that come from a radio receiver of the older types when you tuned from a weak station to a strong one. When the receiver is operating on a weak signal, the amplification in the receiver is adjusted to a large value in order to amplify the weak signal sufficient to be readily audible at the loudspeaker.

Then if you tune to a strong signal, just by turning

the tuning knobs, the same amplification causes that strong signal to be amplified too much, and the result is that the loud and harsh sounds from the loudspeaker are most objectionable. In fact, this problem in the receiver made it necessary, in tuning from one station to another, not only to adjust the tuning knobs, but, rather critically to adjust the amplification, the so-called volume control knob.

Q. You mean the operator of the set had to do two things at once?

A. Yes.

The Court: Or else hear his wife complain.

Mr. Adams: Yes, your Honor.

Q. (By Mr. Adams): Well, now, what is this proposal that is on page 14 of your notebook? Will you tell us something about that?

A. ~~That is that elementary~~ proposal to use the strength of the signal in the loudspeaker—

Q. What do you mean by "signal" when you are using it now?

A. At the loudspeaker—

Mr. Adams: (Interrupting): I may say, your Honor, that that word "signal" is one which is used in several different senses by radio engineers and it always means the right thing to them when they are using it, because of the context in which it appears, but to us it sometimes seems very confusing.

The Court: All right.

~~A.~~ The signal at the loudspeaker is an amplified telephone current of audio frequency, that is, of such a frequency that it can be heard when it is amplified and reproduced.

Q. In other words, you mean there the thing you hear, or the electrical energy which makes the sound you hear?

A. Yes. We might call it the voice current, or some

such name as that. So my first proposal was to take the voice current which had been amplified and delivered to the loudspeaker and to use the strength of those currents to operate an automatic control. Now, the way of expressing that in the entry was that we would devise a volt meter, a meter or some device for responding to the voltage of these currents in the loudspeaker, and to use this device to control the amount of amplification in the receiver automatically.

Q. I notice on page 15 of your notebook that—

The Court: (Interrupting): Before you leave 14, Mr. Adams,—I hope I can interrupt you from time to time?

Mr. Adams: Yes.

The Court: I am going to try to carry this thing along as we go. I think that the witness means that on this date, as shown on page 14, you recognized the problem and you sort of developed a theory that the way to control that, as you say, the obvious method of accomplishing that, that is, you mean that anybody that is experienced in the art would come to that conclusion.

A. Once the problem had been stated to them so that they decided it could be done and should be done, then that is what I thought would be the obvious way of doing it.

The Court: And that way was to have a volt meter that would regulate the strength of the electric current coming through?

A. Yes. The underlying thought there is that if we were to connect the volt meter across the loudspeaker, naturally a loud sound would be accompanied by a far swing of the meter, and a weak sound would be accompanied by only a slight deflection of the meter.

Therefore, the underlying idea was to use this meter deflection to turn the volume control knob in the receiver so that the user wouldn't have to do it. All

that the user would have to do would be tune from one signal to another, and on each signal this meter, associated with the loudspeaker, would turn the volume control.

The Court: That is, in other words, if you had a long arm on a very powerful volt meter—

A. That is right.

The Court: —instead of operating the knob and getting the change there manually, that would do it?

A. Yes. That is exactly the underlying idea. And I was thinking about doing it in a more practical way, but this reference here does not tell very much about the manner of doing it. That was the underlying idea and that was the nature of the suggestion.

The Court: All right.

Q. (By Mr. Adams): Now, you have said that under those circumstances a loud sound would produce a large controlling effect, and a weak sound a weak controlling effect. Now, what would be the practical effect on the operation of the radio receiver if you did use this system of yours to control it?

A. The receiver would have fewer knobs which the user would have to turn. Is that what you mean?

Q. Well, what I am trying to get at is, what would be the effect on the performance of the receiver, if you used the output at the loudspeaker to control the amplification?

A. Yes. As I soon discovered, on thinking about this proposal, there were some characteristics of sound which it would destroy and which I did not want destroyed. Even in ordinary speech and music, this volt meter on the loudspeaker would fluctuate up and down, but I did not want to destroy the normal fluctuations of speech and music, and that proved to be a very serious defect in this first suggestion.

In technical language, we call these fluctuations the contrast of the speech and the music. When we say contrast, we mean the contrast between strong and weak sounds, the contrast between a bass drum and a piccolo.

Q. In other words, this system would destroy that contrast, would it?

A. Yes.

Q. Because, when a strong sound came in, it would cut down the amplification?

A. Yes.

Q. Or when a weak sound came in it would increase the amplification, and the net effect would be to destroy the difference between them?

A. Yes.

Q. What I am going to call your attention to on page 15 is it states at the bottom of the pages in parentheses "better to control by r.f. carrier wave."

What does that mean?

A. That refers to the carrier wave which was not present in the loudspeaker, but which is present in any radio receiver. This carrier wave is the very high frequency oscillation which is transmitted from the transmitter and received at the receiving antenna.

Q. What does r.f. mean?

A. Radio frequency. That refers to the range of high frequencies in which the vibrations are so rapid that the ear cannot hear them directly. They are so rapid that they can be radiated through the ether.

Q. Well, now is that term—you notice that r.f. appears in that statement. Is that term r.f. used to contrast the frequency with the frequency you were proposing to use before, the audio-frequency?

A. Yes, exactly. That refers to the frequency of the radio waves as distinguished from the lower frequency of the ordinary audible waves.

Q. Will you tell us what is the significance of this entry on page 15?

A. The significance is that this carrier wave is always present in the receiver, even if the sound entirely stops for a moment. It is present in about the same strength, even if the sound becomes very strong for a moment. This radio frequency carrier wave furnished a source of control which would be steady, which would not fluctuate with the strength of the sound, and once appreciating that the original proposal would wipe out the contrast in the sound, then it was logical to look for something which was present all the time and which could be used for control without wiping out this contrast.

Q. Now, let me make sure that your Honor understands right in there. I might ask the witness the questions on the subject. Does this carrier wave which comes from the transmitting station to the receiving station carry, in a sense, the sounds which you want to hear?

A. Yes, that is why we call it the carrier wave. It is a radio wave that has superimposed on it the fluctuations corresponding to the sound wave.

The Court: Is that what they illustrate in the Radio City demonstration where they have it highly magnified and show on an electric screen, for instance, the guide hits these bells and you get one reaction, and hit something else and you get something else?

A. Yes. Yes, the vibrations which you see and which are in step with the sound are the vibrations which we say are of low frequency; they are really of high frequencies, but we are accustomed to dealing with so much higher frequency that we call those the low frequencies, and then those low frequencies, or audible frequency vibrations, are superimposed on this wave which vibrates so rapidly that we cannot see or hear it, and these low frequency vibrations are carried through the

open space on this high frequency wave. Then in the receiver, the high frequency wave has to be picked up. It has to be amplified, then it can be put through the process we call "detection" to recover the low frequency wave again, and after recovering the low frequency wave, then that can be amplified, and fed to the loudspeaker.

Q. When this carrier wave is changed so as to carry the sound frequencies, do you speak of it as a modulated carrier wave?

A. Yes, we say that the low frequencies are attached to the carrier wave by the process of modulation.

Q. Do you speak of those low frequencies as the modulation frequencies?

A. Yes.

Q. I inject those terms because they are used throughout the patent and the claims. Is this also true, Mr. Wheeler, namely, the strength or the loudness with which you receive a particular transmitting station, with which you hear whatever it has to send out, is determined by the strength of the carrier wave with its accompanying modulation, at the receiving set?

A. Yes.

Q. I want to bring out this further idea, and that is that that determines the strength at which you receive all of the different sounds that that carrier has to carry, is that right?

A. Approximately. The relation is this. The original sound has some strong passages and some weak passages. These are all put on the carrier, and the stronger passages produce a strong modulation of the carrier and the weak passages produce a weak modulation, just a little fluctuation of the carrier strength. Now, when it comes to the receiver, if the carrier is weak, the strong modulation is reproduced as a weak

sound, and the weak modulation would not be heard at all. But, if the carrier is strong, then the strong modulation becomes a loud sound and the weak modulation becomes a weak sound, and that is exactly the desired relation.

Q. But they would be in their correct relation to one another?

A. Yes.

Q. The reason I go through this is that I want to ask this one question, and that is; you have pointed out that if you attempted to control the operation of your receiving set by taking the voltage from the loudspeaker, it would destroy the contrast. Now, what I want to ask you is, if you controlled the operation of your set by controlling, or by taking a voltage from the carrier wave and using that to control your set, would you then destroy the contrast?

A. No.

Q. Well, now will you just tell me briefly why you would not destroy the contrast?

A. It is just this idea I was trying to express, that the carrier is present continuously and it is present during the weak modulation and during the strong modulation, and the carrier itself does not change very much. It does not change nearly as much during modulation as the strength of the sound of modulation changes. So that we say the carrier is constant even during weak or strong modulation, and, therefore, the carrier gives us a direct indication of whether we are receiving a weak signal or a strong signal.

Q. Now, "signal" you are now using in the sense of the modulated carrier, is that right?

A. That comes in on the antenna, yes.

Q. Now, will you tell me what all these various notes are on page 15 above that statement that we have been talking about?

A. They are generally fragmentary circuit arrangements for using a vacuum tube to perform the function of this loudspeaker volt meter.

Q. Well, were they preliminary to this remark, was this remark a conclusion derived from them, or have they any relation?

A. There isn't any direct relation. The loudspeaker volt meter idea was being carried forward on that page in the first two or three diagrams and in those cases the vacuum tubes were connected in such a way that they responded to the loudspeaker voltage; they were coupled directly with the loudspeaker.

Q. Let me ask you this, Mr. Wheeler: In that system where you took the control voltage from the loudspeaker or at the point where the loudspeaker is connected, what were you going to do with that voltage actually in the proposals on page 15?

A. First I was going to rectify this loudspeaker voltage in order to derive from it a biasing potential, a steady biasing voltage, and then I was going to use this biasing voltage to control the amount of amplification in the receiver.

Q. How were you proposing to do that?

A. In order to do that, I was going to put the biasing voltage on the grids of the amplifier tubes in the receiver. It was well known that a negative biasing voltage applied to the grid of an amplifier tube would reduce its amount of amplification, and that is the principal I was proposing to employ.

Q. Then, as I understand it, you were going to take this voltage derived from the loudspeaker terminals of the set and use that to negatively bias the amplifier tubes?

A. Yes.

Q. Well, now, at the bottom of page 15 where you

say "better to control by R.F. carrier wave", how were you going to effect the control if you used the R.F. carrier wave?

A. We would no longer use the voltage at the loudspeaker in order to derive this bias for control purposes. Instead, I was proposing to derive the control from an early part of the receiver where the radio frequency carrier wave had not been separated from the modulation. We would use our carrier wave before it was separated from the modulation.

Q. After you got a voltage from that point, were you then going to control the amplification by using that to bias the grid of the amplifier tube?

A. After putting it through a rectifier, in order to change the carrier wave to a biasing potential.

Q. Now, did you carry forward with that idea and devise any scheme for doing that?

A. Yes.

The Court: Just a minute, witness, I am not sure I understand what you mean by "biasing potential".

A. We use the words "voltage" and "potential" more or less synonymously, and the idea of biasing is the idea of applying a voltage or potential to the grid of the vacuum tube in such a way as to oppose the flow of electrons through the tube. The electrons normally flow through the tube from the hot electrode, which we call the filament or the cathode, to the cold plate or anode; "plate" and "anode" for our purposes are synonymous, and the "filament" and "cathode" mean the same thing in our usage. Now, the grid is the third electrode which was introduced in the tube many years ago by DeForest and it is the grid which controls the number of electrons which flow from the cathode to the plate.

The Court: Well, would that potential bias—in effect, the way you used it was increasing the negative potential of the grid, was it?

A. Yes, and the electrons have what we call a negative charge, so this negative potential on the grid repels the electrons. It tries to force them back to the cathode where they originate, so a negative bias is a way of decreasing the amount of amplifying action in the tube.

The Court: I may say for your benefit, Mr. Adams, I was just working on it now, just finished taking the proof on an electrolytic process for rust-proofing and I want to be sure that I won't get my terms in the two cases mixed up, and the problem there was, or at least one theory of it was, that the development of a hydrogen blanket on the electrode slowed up the process, and their problem there was, too, that is, based upon that theory of the case, was to decrease the negative charge. Here your problem is to vary it, decrease it or increase it, depending upon whether you wanted an increased volume or decreased volume.

A. Precisely.

Mr. Adams: That is right, your Honor. The problems are somewhat alike. I think as a matter of fact that the terms of anode and cathode as used in radio tubes were derived from the electrolytic processes which preceded them.

A. Should I point to that old tube and explain that a little better?

The Court: Well, how does the grid work, as an anode or cathode, or both?

A. No, the grid is a separate idea. The anode and cathode—

Q. (By Mr. Adams, interrupting): Will you point out in this tube which I show you the filament and the grid and the plate.

A. The filament is a hair-pin of wire that we can hardly see in the center of the tube and it is just like the filament of an ordinary electric bulb.

The plate is the large cylindrical electrode on the outside in this tube, and the grid is a spiral wire in the shape of a spring which is interposed between the filament and the plate.

The Court: All right, go ahead.

A. Now, what I was just saying is that the electrons originate in the filament in the center of the tube and flow toward the plate or anode, and that process was old in the Fleming valve, even before DeForest put the grid in the tube. Then the grid is interposed so that it partially obstructs the flow of electrons from the filament to the plate.

Q. You mean physically obstructs it?

A. Physically to a very slight extent, because the grid wires are far enough apart to let the electrons flow through, but the idea that DeForest had was that he would like to have a shutter in the tube which he could open and close and control the number of electrons he permitted to pass from the filament to the plate.

Now, it was obviously impossible to put a shutter in a vacuum and have a handle stick out, so he proposed this electrical shutter in the form of a grid.

The grid wires actually are fixed, but he said that by putting a variable negative charge on the grid wires, negative or positive, he could either repel or attract the electrons from the cathode over to the plate, so the effect of the grid is an electrical shutter, and the spacing between the grid wires which is actually fixed, really is opened and closed by the amount of negative charge on the grid wires. When there is a sufficient negative charge on the grid wires, all the electrons are shut off, and there are all stages of charge in between a complete cutting off of the current in the tube and permitting the maximum current to pass through.

Q. Will a relatively small change of potential on

the grid produce a relatively large change in the amount of energy going from the cathode to the plate?

A. Yes.

Q. And is that energy that flows from the cathode to the plate under the control of this relatively small change in potential on the grid generally proportional to that change?

A. Yes.

Q. Now, is that why it is referred to as an amplifier?

A. Yes, exactly.

Q. Now, tell me to what part of the circuit of the radio set is the grid connected?

A. Take the first tube in the receiver as an example. The grid is connected to the circuit which comes from the antenna. The modulated carrier signal which is received out of the air, comes from the antenna as an electric current or electric voltage and is applied to the grid of the tube.

Q. In other words, it is the modulated carrier which acts on the grid?

A. Yes.

Q. And as I understand it from what you said, that in effect releases or controls a larger amount of energy which flows from the cathode to the plate or anode, and that is used in this amplified form for the rest of the set, is that right?

A. That is the idea. I should explain the real source of this energy which comes, which is released in the plate circuit.

We have to have a battery associated with a triode tube, either a battery or some other source of power, so the energy or power in the circuit between the filament and the plate is obtained from this local battery, and strictly speaking, it is not obtained from the electrons themselves, but the flow of electrons controls the amount of energy which is released from the battery, just as

if we had a mechanical relay, so the grid controls by this indirect amplifying process the amount of energy which is released from the local source of power, the battery, for example.

Q. Does that battery supply these electrons which flow from the cathode over to the plate?

A. Yes. All the electrons which are released from the cathode have to be supplied from the battery, because there can be no manufacture of electrons. They merely flow around the circuit.

Q. Well, now, in a radio receiving set, do you sometimes use more than one of these tubes to secure amplification, repeated amplification?

A. Yes. It is customary to use anywhere from four to a dozen or so.

Q. After the signal has been amplified—well, now, let me ask you this: What is the characteristic of the energy which is in the plate circuit of this last amplifier tube? At what frequency does that energy appear there?

A. At the same frequency as the kind of a signal that is applied to the grid. That is, in the first tube I mentioned, we put on the grid this modulated carrier frequency signal, and, therefore, there appears in the plate circuit an amplified signal of the same carrier frequency with the same modulations on it.

Q. What you have done so far in this set, then, is to make your received carrier wave, with its modulations, louder, or stronger, rather, than it otherwise would be; is that right?

A. Yes.

Q. What do you do to hear what it has carried with it?

A. Then we have to put this modulated carrier signal through another process which we call detection. I like to think of detection as the opposite of modulation,

because in the transmitter we put these sound waves on top of the carrier by this modulation process. In the receiver we put the resulting modulated signal through the detection process which recovers the sound modulation, and the detector puts out, therefore, after performing its operation, an ordinary telephone current, a current of such frequencies that it can be used directly in a telephone receiver or amplified for a loudspeaker.

Q. When you say "amplified," do you mean there is some further amplification in the set after detection?

A. Yes; that is customary.

Q. And that is so you can hear it in a loudspeaker instead of in a head telephone?

A. Yes.

Q. Well, now,—

Mr. Adams: Does that make clear to your Honor, or does it answer your Honor's immediate question as to what happens inside of one of these tubes?

The Court: I think I almost see it. It will probably come out clearer. But you put it another way. What happens is by placing the grid in there you, in effect, say to these other waves, "Come along. If you are going along with us you got to get to be our size, or vice versa."

A. Yes.

The Court: And from there on they go through the circuit. That is the way I understood it.

A. Yes. If there is a rapid pulsation of the charge on the grid then the electrons coming through the tube come in rapid bursts.

The Court: In other words, if you are going to dance with us you will have to get in step right here.

A. Yes.

Mr. Adams: That is right.

Q. (By Mr. Adams): Now, I find on page 17 of your

notebook a continuation of this discussion of automatic volume control, and will you tell me what that proposes?

A. These are proposed circuit arrangements in the receiver for carrying out the suggestion of controlling by the radio frequency carrier wave.

Q. Well, now, will you tell us what you proposed there?

A. My first proposal for this purpose was pretty crude and pretty complicated. The first diagram on page 17 has a number of blocks in it that are labeled by abbreviations for different kinds of apparatus. The first block is "r.f. amplifier". That is the radio frequency amplifier in the receiver which comes ahead of the detector. That includes the first tube in the receiver. Then the second block directly on the right is called "r.f. detector". That is the detector I mentioned which recovers from the modulated carrier its modulation in the form of sound or telephone currents.

Now, they were ordinary pieces of apparatus in any receiver. But the block just below, which is labeled "c.f. modulator", was a new device that I was introducing for this control purpose. "C.f." stands for "control frequency".

I knew that in the receiver we could separate any different frequencies which were put on this carrier and use one frequency for one purpose and another frequency for another purpose. So this proposal was to add another modulation on the carrier in the receiver of such a frequency that this part of the signal could be separated from all the other parts we had to use. Then the other three blocks in that diagram, called "c.f. amplifier", "c.f. detector" and "control device" were arrangements for selecting this control frequency and using that to control the amount of amplification.

Now, the significance of this control frequency is that it was to be such a fixed modulation as was not subject to any of the contrast present in the sound modulation. It is a little difficult to explain but that was an indirect way of using the carrier amplitude instead of the sound amplitude for obtaining the control.

Q. I notice on that page it says "Adapted to representative receiving set". Did you ever adapt it to a receiving set?

A. No. That does not refer to any experiment. It is merely descriptive of—what that statement means is this: The apparatus as shown in these diagrams is shown in detail on the second diagram on page 17, except for the apparatus which would be in a representative receiving set.

Q. Did you ever carry this particular proposal into any practical use?

A. No.

Q. What are all those little blocks and circles down at the bottom of page 17?

A. That is a more elaborate diagram as to how the same proposal at the top of that page would be incorporated in a receiving set having many tubes. The circles referred to the different tubes in the receiver and the squares to the auxiliary apparatus which goes with those tubes.

Q. When you say "auxiliary apparatus", was there something that had to be added to the receiving set if you were to use this particular proposal?

A. Yes. About half of the elements in this diagram, both tubes and auxiliary circuits, would not be in an ordinary set and would have had to have been added for this purpose.

The Court: All right. Come back at two o'clock.

(Whereupon a recess was had until 2:00 o'clock P. M. of the same day, Wednesday, October 25, 1939.)

Detroit, Michigan.
Wednesday, October 25, 1939.
2 o'clock P. M.

Court met pursuant to recess.
Parties present same as before.

HAROLD A. WHEELER, was thereupon called as a witness herein, and having been previously duly sworn, testified further as follows:

Direct Examination (Continued)

By Mr. Adams:

Mr. Adams: At the close of the morning session we were looking at page 17 of Mr. Wheeler's notebook No. 6, and as I recall it, Mr. Wheeler had just explained that the proposal which was there shown had considerable auxiliary apparatus and was never actually carried further so as to be embodied in the practical receiving set.

Q. (By Mr. Adams): Now, will you tell us, Mr. Wheeler, what is next shown in your notebook as to your work in connection with this problem of automatic volume control?

A. A few days later, on July 20, 1925, I made some notes on page 32.

Q. What do they show?

A. Near the bottom of that page is the entry. It is entitled "Autovol volume control." That was a trick name that I used occasionally, but not very much.

There we see a block diagram with two rows of symbols. The system shown is along the same lines as that I just finished describing in that it has a control frequency modulator, which is labelled "c.f. modulator", in the diagram, and that is additional apparatus in the

receiver, and it has further additional apparatus, the same as before, labelled "c.f. amplifier and detector," in the lower row on the diagram. I think there is very little difference there between that and the thing I just described.

Q. I notice it says "In this arrangement two or three extra tubes would be required." Can you tell us what that means?

A. I thought I could get this arrangement down to where only two or three extra tubes would be required, instead of a great number as in the preceding diagram, but as I mentioned about the other diagram, this was never tried, so that was merely an estimate on paper.

Q. What was your next work along this line of automatic volume control, Mr. Wheeler?

A. The next work I recorded—I should explain that when I had a thing like this in mind it was seldom that I recorded more than a small part of the things I thought about it, but I tried to keep a record which would be an indication of my train of thought, as well as of specific examples that I thought would work.

Now, along this same line, while it was not exclusively applicable to this automatic volume control I find some notes on pages 77 to 79, the first of which is dated December 2nd, 1925, and is entitled "AC self-rectified plate supply for direct current voltage amplifier."

In the suggestions I have made for automatic volume control one thing had already shown up as a difficulty in a circuit arrangement for that purpose, and that is that I would have to have an extra battery in the vacuum tube circuit which I proposed to develop in this rectified grid bias potential.

Q. When you say extra battery you mean beyond any battery that ordinarily would be in the set?

A. Yes. It was customary in receivers to use a single

battery, which we called the "B" battery to furnish, or I should say to carry the electron current through all the tubes. This one battery could be connected to all the different tubes, even though they were in different parts of the receiver, and it was very important to use only one battery for all the tubes, because the "B" battery was a massive and expensive piece of the receiver. The "B" battery is the large sized battery, about as big as a storage battery, that we used to have to replace so often in the receivers.

Now, what I had discovered in my earlier notes was that the vacuum tube circuit used to develop this biasing potential always had an extra battery in addition to the common battery for the receiver, and that would have another "B" battery which would be a nuisance for replacement and an extra cost in the receiver.

So, this proposal on pages 77 to 79 was an idea noted while reaching out for something to get away from this extra battery. What I tried to do was to put alternating current directly through a transformer on the tube which would otherwise have to have a separate battery, and I thought that this alternating current would be easier to get because a small transformer could be used and, at least, it wouldn't have to be replaced.

Q. It still would be an extra source of energy, wouldn't it?

A. Yes. This suggestion recorded on these pages was not very good. I did not think very much of it then, and I don't think very much of it now, but it was just an attempt to get away from that extra battery.

Q. I notice it says here in the diagram on page 77 at the extreme right of the second series of circles "110 V. A. C." What did that signify?

A. The symbol just under those letters is the alternating current transformer which was used to supply the power individually to each tube.

Q. Where did you propose to get that energy that went through that transformer?

A. From the 110 volt circuit, lighting circuit.

Q. The ordinary house lighting circuit?

A. Yes.

Q. I may just interject there a question: Where were you at the time, say, in December, 1925, when you were making these entries along on page 77 to 79?

A. After spending the summer of 1925 at the Hazeltine laboratories I entered the post-graduate physics department at Johns Hopkins University, and I spent the winter from 1925 to 1926 and the two following winters studying at Johns Hopkins, but still keeping in close contact with the laboratories.

Q. Well, now—

A. (Interrupting): Excuse me. I intended to mention with reference to these pages, while there is very little reference to automatic volume control we do find a note on page 79 in the middle of the page, "May be used on automatic volume control device finally."

Q. Did you finally use this proposal?

A. No.

Q. What is the entry on page 79 under the date of December 8, 1925?

A. Well, after getting started in the University for the winter I naturally turned my thought back to how this automatic volume control device might be made to operate. Up to that time I had been too busy on other things to construct any apparatus; and, of course, the apparatus available at the University was not for personal uses like this, so I was forced to study its operation on paper, and this entry at the bottom of page 79, and continued on page 80, gives some curves that I developed in order to predict on paper how this automatic volume control would operate.

The question I had in mind was how much variation of signal strength could be wiped out by the system with the actual apparatus which was available. That is, using tubes and amplifier circuits which were then in the receivers, and in addition the automatic volume control device.

Q. Well, on these two pages, then, 79 and 80, under date of December 8th, you didn't propose any actual new circuit arrangement or connections of apparatus?

A. No.

Q. Is that right?

A. That is right.

Q. Where do you find your next proposal with respect to the actual apparatus?

A. On page 83. About that time, that is, in the early part of December, 1925, I decided it was time to build up a receiver to try out this automatic volume control, which I was confident would operate successfully, and the first chance I was going to have to try it out was at my home during the Christmas holidays. So, on the upper part of page 83 under the heading, "R. F. amplifier unit for experiments," we find several fragmentary diagrams which I made in considering what kind of an amplifier I would make in order to try out the automatic volume control.

Q. What do you mean when you there say "amplifier unit"?

A. The receiver I was planning to build was a unit receiver. That is, it was to be assembled by putting together a number of separate units, each one built on its own small panel, and the notes on the top of page 83 referred to the construction of a typical one of those units.

Q. What actual parts were going to be included in one of those units?

A. One unit would include one amplifying vacuum tube and the associated tuned circuit in the carrier amplifier in which such a unit was to be used. We called it one stage of the amplifier, when we refer to the vacuum tube, and the piece of apparatus which is used to couple one tube to the next. So that, if we have that much apparatus in one unit we call it one stage, and we can put those units together to build up any number of stages. This was a unit with one stage of amplifier on it.

Q. When you say one stage and several stages do you mean that the first stage would amplify the signal to some extent and then feed it into the next one which would then amplify it some more?

A. Yes.

Q. Does this diagram on page 83 under the heading of December 10th show this system of automatic volume control which you were proposing to use?

A. That is another of the suggested arrangements, but I had not selected any one of these arrangements yet for the receiver I was planning to build. This arrangement is different from the preceding arrangements I described, but also had the property that the strength of the carrier was the thing which determined the amount of control; that is, the amplification was to be controlled in accordance with the strength of the received carrier signal.

Q. Will you tell us by reference to this diagram just what you proposed to do here in order to get the automatic volume control? Were you still proposing to bias the grids of the amplifier tubes to control their amplification?

A. Yes.

Q. And, how did you propose to get the voltage or potential that was to be used to bias those grids?

A. I used an extension, or I rather suggested in these notes, an extension of the super-heterodyne principle.

Now, the super-heterodyne was a particular type of receiver which had an arrangement for securing very large amplification of the carrier voltage, that is, of the carrier signal strength received on the antenna.

Now, here I used a double super-heterodyne receiver. I don't know as I need to describe the super-heterodyne process in detail, but I went through that—the signal, rather, was to go through that process twice in the receiver in order to be amplified and operate the final rectifier for developing the bias. Now, that final rectifier is located at the extreme right-hand end and is labelled "detector" in the diagram just under the date of December 10. This involved—

Q. Labelled "det", is that the one you mean?

A. Yes. This involved not only all the apparatus in a normal super-heterodyne receiver, which appears in the upper row of symbols in the diagram, but also involved additional apparatus which appears in the lower row, to the extent of several additional tubes and their associated circuits, these having no function at all except for the automatic control.

Q. Well, I gather, then, it was not a simplification of your previous scheme; is that right?

A. The diagram I just referred to, I don't think was. The diagram at the bottom of the page just below, I think, is a little simplification of anything I had before.

Q. Did you devise this to secure an improvement on your previous scheme?

A. Yes.

Q. Wherein would the improvement lie?

A. I would not have to introduce the control frequency modulator and the control frequency circuits which were part of the earlier proposals.

Q. Did you ever actually carry this proposal to practical form in a radio receiver?

A. No.

Q. What did you do in your attempts to devise a satisfactory system?

A. The next few pages show the notes I made from day to day while I was turning over in my mind what kind of a control system I could best incorporate in this receiver I was planning to build, and on page 84 there are three diagrams. The upper one is a continuation of the preceding page in which I have some additional apparatus added into a super-heterodyne receiver, only two tubes in addition to the normal number of tubes in the receiver. In fact it says under the diagram, pointing to one of the tubes, "Possibly not needed." And then it says, "One or two extra tubes used."

The thing I was trying to do was minimize the number of extra tubes because each tube was then a large part of the cost of the receiver.

On the second diagram on page 84 it shows an arrangement of units, rectangles, and that is one arrangement of amplifier stages which I was proposing to incorporate in this receiver. This is not the arrangement I finally used. It is an arrangement of stages which was adapted for the system of control shown at the top of page 84.

Q. I notice a series of numbers under the date of December 11th, No. 1, and all the way up to No. 9, with some figures below them. Can you tell us what they mean?

A. The numbers refer to the successive stages or successive tubes in the receiver. And just below the numbers are notes indicating the relative strength of the signal, the signal voltage, after it had been amplified by one stage, and two stages, and so on.

These merely indicate how the signal was to build up in its strength as it passed through the amplifier.

Q. Now, what does the number under the first number 1 indicate?

A. One thousandth of a volt.

Q. Then under number 2?

A. One hundredth of a volt.

Q. Under number 3?

A. One tenth.

Q. And under number 4?

A. One volt.

Q. Does that indicate that the signal is successively made stronger as it goes through the receiver?

A. Yes.

Q. Is that what the amplifier does?

A. Yes.

Q. Now, I notice that the numbers continue to get bigger. Will you explain what they are?

A. No. 5 and No. 6 are labelled 10 and 100 volts. I was planning to amplify the signal at the carrier frequency, that is, at the same frequency it came in on the antenna, in two additional stages more than we would use in the ordinary receiver. Now, in the diagram in the middle of page 84, the fifth unit, labelled No. 5 at the top, is also labelled "Amplifier F-1." The significant thing about that amplifier is that the signal in the receiver did not go through that amplifier on its way to the loudspeaker. It only went through that amplifier into the control circuit. Now, therefore, the significance of these numbers in this diagram is that I was proposing to add additional amplifier stages at the carrier frequency, and a separate rectifier or detector to develop the bias potential, and that this part of the apparatus would have no use in the conventional part of the receiver.

Q. In other words, the rest of the receiver, except for the automatic volume control, wouldn't want voltages as high as that?

A. That is right.

Q. Also I notice just below that some more circuits. Are they part of the automatic volume control system?

A. That is a proposal as to how to avoid the use of the extra battery in the control circuit. That is an extension of the notes I referred to on pages 77 to 79. Finally I never did use it.

Q. Now, I notice that on page 85 there is another entry under date of December 10th. What does that connect up with in your notes?

A. Here are two additional diagrams showing possible arrangements of amplifier units. I was then making a note of the several possible arrangements which might be incorporated in the receiver and the purpose was to get a better appreciation of the disadvantages and advantages of each arrangement so I could select the most promising arrangement for the receiver.

Q. Were you trying to improve the result, or simplify it?

A. Both, but I think the simplification was the principal problem, because the complicated circuit arrangements I have proposed would have given very good results.

Q. Now also I notice there is a further entry on page 85 under the date of December 11th. What does that relate to?

A. That is another arrangement of units in which I was still trying to reduce the number of additional tubes needed in the receiver.

That arrangement still had the disadvantage of requiring the extra "B" battery for the tubes used in the control circuit, as noted on that page, where it says "Necessitates extra 'B' battery."

Q. Now, on page 86, drawn the length of the page, I find a rather elaborate circuit diagram. Will you tell us what that is?

A. That is the first detailed circuit diagram that I made in planning this receiver. It shows all of the essential circuit elements of a super-heterodyne receiver.

Finally, I had reduced the number of additional elements so that I expected to need only the normal number of tubes in the receiver. I thought I could do this by obtaining the biasing potential from one of the tubes already in the receiver, namely, the normal detector in the receiver.

Q. Which tube is that as shown in the diagram?

A. No. 5.

Q. Will you just briefly tell us what each one of these tubes does in the actual receiver?

A. Yes.

Q. What does No. 1 do?

A. No. 1 is the first amplifier tube and it also changes the carrier frequency to a lower carrier frequency. Now, this is an operation I haven't described yet.

Q. Is that what you call the super-heterodyne principle?

A. Yes. Its purpose is not to alter the nature of the signal. The signal still remains a modulated carrier signal, but by reducing the carrier frequency to a lower frequency in this operation it becomes easier to amplify it.

So as far as the operation of the receiver is concerned this stage is just an amplifier.

The second, third and fourth tubes are also amplifiers to amplify the carrier signal before it is put through the process of detection.

Tube No. 5 is the ordinary detector of the super-heterodyne receiver, and similar to the detector in any other kind of receiver, but in this detector circuit I included some additional elements which would enable me to derive from it the biasing potential which ordinarily would not be derived from the detector. I mean the detectors used in those days were used for just one purpose, they were used to recover the modulation from the carrier, so I complicated this ordinary detector circuit and added an additional battery which is symbolized just below the

tube at the bottom of the diagram, several vertical lines, with minus and plus signs at the ends. Those are inserted at the lowest horizontal line in this diagram on page 86.

The tubes 6 and 7 are the usual audio amplifier tubes which are used to amplify the audio-frequency currents after they are obtained from the detector.

Now, in the output of tube No. 7 at the right-hand end of the diagram there is a symbol which has two circles connected by a curved line. That symbol is intended to look like a pair of telephone receivers with a head band between them, but actually a receiver like this would work into a loud-speaker. The symbol was used interchangeably for a loud-speaker or head telephones.

Q. What do those letters A and B over at the extreme right denote?

A. Those are the common batteries for all the tubes in the receiver.

Q. What did the "A" battery do?

A. The "A" battery heats the filaments of the receiver to the temperature required for emitting electrons. It lights the filaments.

Q. What did the "B" battery do?

A. The "B" battery supplies the local power for each stage, that is, the same "B" battery for all of the stages. The "B" battery supplies the power which is controlled by the grid in each of the amplifying vacuum tubes.

Q. Did all of the tubes in this receiver use that "B" battery?

A. Yes. Then as I mentioned, there is an additional battery, in fact, two additional batteries shown near tube No. 5 which were incidental to the control operation of the set.

Q. One of them is much closer in the drawing to the tube, to the circle, No. 5?

A. Yes.

Q. Which is the only way I can identify it in words. What does that battery do?

A. It furnishes an adjustment on the bias of the detector tube.

Q. Manual adjustment?

A. Yes. We haven't talked about the effect of the bias in the detector, but the detector tube is a little different than an amplifier tube.

Q. In structure?

A. It has about the same structure, and may be exactly the same structure, but it is operated differently. In an amplifier tube we want flowing through the tube all the time a large number of electrons, because in that way a change in the negative charge on the grid controls the maximum amount of current. The current through the tubes is proportional to the number of electrons passing through. On a detector the conditions are a little different. In the detector we are not so much interested in amplifying the signal; we aren't so much interested in the amplifying action of the tube, although that is incidentally important. We are interested in changing the form of the signal.

Now, it frequently happens that we can change the form of the signal better by putting a fixed bias on the detector tube. That has nothing to do with the control bias that I talked about for the amplifier tube.

This fixed bias on the detector is made sufficient to reduce the number of electrons flowing through the tube to a relatively small number when no signal comes in. Then, when a signal comes in, the signal produces both positive and negative voltages on the grid alternately. The positive waves of the signal tend to wipe out, tend to counter-act this initial negative bias on the grid, and cause a relatively large burst of current to flow through the tube.

The negative pulses from the signal on the grid try to reduce the number of electrons, but the number is already so small that it can't be reduced very much. The net result is that the positive and negative voltage pulses of the signal don't have an equal effect on the electron stream.

Q. As they would in an amplifier?

A. Yes. In an amplifier we want every voltage pulse of the signal to be amplified and to have the same effect, but in a detector we want them to have different effects.

The Court: Mr. Adams, I am afraid I will have to excuse you gentlemen for this afternoon. I don't think this will happen again, but you may come in in the morning. How about 9:15, is that all right for you?

Mr. Adams: Yes, your Honor.

The Court: Make it 9:15, then. We will take a recess.

Detroit, Michigan.
Thursday, October 26, 1939
9:15 o'clock A. M.

Court met pursuant to adjournment.

HAROLD A. WHEELER, was thereupon called as a witness for and in behalf of the Plaintiff, and having been previously duly sworn, testified further as follows:

Direct Examination (Continued)

By Mr. Adams:

Q. At the close of the session yesterday, we were discussing the automatic volume control system which was disclosed on page 86 of your notebook, under date of December 12, 1925, and particularly we were discussing the function of the so-called C battery which adjusts the

C bias. Now, will you continue, Mr. Wheeler, and explain in practical effect what that does when you adjust that C battery?

A. That is a manual adjustment for the purpose of counter balancing the grid bias and the plate potential in their effect in that tube.

Q. That is the detector tube?

A. Yes, No. 5.

Q. And is it from that tube that you get the potential for automatic volume control?

A. Yes, that was the particular arrangement that I had added to the normal detecting function of this tube in this circuit.

Q. Well, the amount of potential that you secure for automatic volume control, does that depend upon the adjustment of that C bias battery?

A. Yes, quite critically.

Q. And will it depend upon the age of that battery?

A. Yes.

Q. What do you mean by that?

A. These batteries deteriorate gradually, and they have to be left in the receiver for a reasonable life, even though their voltage is constantly deteriorating. Now, this adjustment was sufficiently critical so it would have to be repeated perhaps every day or two as the batteries deteriorated, and each time the set was turned on the conditions might be a little different.

Q. Will you tell us, Mr. Wheeler,—I do not believe you have—how it was that this particular proposal, as shown on page 86, differs from the previous proposals?

A. It follows a fragmentary suggestion which we find just below the middle of page 85, entitled "Combining control and signal detectors." Previously, that is in the earlier suggestions, I had used a signal detector in the receiver in the ordinary way it was used in receivers of that day. The ordinary way was to

amplify the signal to a rather low voltage, much greater than the signal was received, but a voltage only of the order of a tenth or a few tenths of one volt, and to apply that amount of amplified signal to the detector. In that arrangement the signal strength at the detector was not great enough to secure directly from that detector the required automatic volume control potential. Therefore, I had added in the previous suggestions more or less elaborate apparatus for further amplifying the signal and using an additional rectifier, separate from the detector, to obtain the bias for the control.

Now, in this arrangement I decided that if we put a little larger signal voltage on the ordinary signal detector in the receiver, that detector circuit could be modified so as to be used at the same time for supplying the biasing potential to control the amplification. That was the suggestion on page 85, and that was incorporated in the complete diagram on page 86.

Q. Well, now, when you talk about those prior proposals which did not use that system, do you refer to the one under date of July 11th, which added the control frequency? That is on page 17.

A. That is one of them.

Q. Is that sometimes called a pilot frequency?

A. Yes.

Q. Now, do you also have in mind the so-called D. C. amplifier that you refer to?

A. Yes.

Q. And then I think the other one was the system where you had various modifications for using a superheterodyne and taking the carrier off before detection; is that right?

A. Yes.

Q. That I think was under date of December 10th, 1925, on page 83. Is that right, Mr. Wheeler?

A. Yes. Pages 83 to 85.

Q. Was there more than one such arrangement?

A. Yes. They might be classified as three arrangements. The first one was to subject the carrier to a second super-heterodyne process to develop another carrier frequency which was to be further amplified and rectified to obtain the bias.

The second arrangement, which is at the bottom of page 83, proposes further amplification at the same carrier frequency which exists in a super-heterodyne receiver, but beyond the amplification which would ordinarily be used.

The third arrangement, which is found at the upper part of page 85, proposes further amplification at the second harmonic of the carrier frequency, that is, at a higher carrier frequency twice as great.

These arrangements all had in common the intention of further amplifying the carrier signal more than it would ordinarily be amplified for the signal detector.

Q. Well, now, with reference to this arrangement, which is under date of December 12th on page 86, is that a system which overcomes some of the defects of the other systems?

A. It has the advantage of simplification, because there are no tubes added to the receiver for the purpose of obtaining the control. That is something I was working toward all the time. And here I thought it could be accomplished with this arrangement in a satisfactory manner.

Q. Did you make any plans to actually build this type of receiver as shown on page 86?

A. Yes. This is the circuit that I planned to build into a receiver during the Christmas holidays.

Q. I find on page 86, under date of December 15, 1925, some drawings that look like apparatus. Will you tell us what they are?

A. That is a sketch of the physical arrangement of a typical unit. It is one of the units which I planned to use in assembling this receiver.

This particular unit is a carrier amplifier unit. We see in the diagram the vacuum tube at the left side, a large coil, and a variable condenser in the middle. They are surrounded by a shield box shown in dotted lines.

Q. Now, on page 87 I notice some computations. Will you tell us what they are?

A. These were computations involved in designing the parts for these amplifier units. They relate especially to the design of the carrier amplifier units, such things as the number of turns on the coils, the size of the coils and so forth.

Q. Now, will you look at page 88 and tell us what that page discloses?

A. The long diagram on that page is essentially similar to the one on page 86. The principal difference is the addition of neutralization in the amplifier stages. This was the invention of Professor Hazeltine in which I had been previously interested; and I decided that it would be a great advantage to include it in the superheterodyne receiver.

Q. Will you point out to us in that circuit the tube from which you get the potential for automatic volume control?

A. No. 5.

Q. And can you also tell us what tube is controlled?

A. The lowest horizontal line in that diagram goes from the output circuit of tube No. 5 back to the grids on tubes Nos. 2 and 3. No. 3 tube is not shown in the diagram because it is arranged in the same manner as No. 2. Those two tubes, No. 2 and No. 3, were the controlled amplifier tubes in this circuit.

Q. Under that diagram I notice a label over at the

left says "Grid volts." Will you explain what that heading means?

A. On that line, underneath the diagram, there is a number underneath each tube. That number denotes the approximate signal voltage which I intended to apply to the grid of that tube. The voltage under the first tube is a very small voltage because it has not yet been amplified at all. That is the voltage which would arrive at the first grid from the antenna. The value is one one hundred thousandth of a volt, or ten micro volts, as we sometimes say, ten millionths of a volt.

Then, as we go along the line, we see increasing values until we get underneath tube No. 5 we see the figure 10 minus. That means that the amplifier was capable, or, at least, was intended to be capable of supplying as much as 10 volts to the detector tube, but actually the tube would not receive that voltage. Such detector tube circuits were not operative on a voltage more than around one volt, and the control arrangement was intended to hold down the voltage to the normal operating level for this detector tube.

Then, under tubes No. 6 and No. 7, we see larger voltages. Those are very rough indications of the audiofrequency or modulation frequency voltage which would be applied to the last two amplifier stages. They were rather upper limits of the voltage than representative values, because in designing a receiver like this we can always reduce the amount of amplification. The preliminary studies are directed to obtain enough amplification.

Q. How much voltage did you plan to have available for control purposes in this design?

A. A maximum of about 10 volts.

Q. What does the rest of the diagrams on that page show?

A. Partial circuit arrangements of some of the units.

Q. You mean the units of the set you planned to build?

A. Yes.

Q. In this circuit diagram that you have just referred to on page 88 I notice just below the tube No. 5 what appears to be a battery similar to the one which you called a C battery in the diagram on page 86; is that a C battery?

A. Yes. In fact, the entire arrangement of the detector circuit is similar.

Q. Well, does that battery have that same effect there of critical adjustment of the action of the detector tube?

A. Yes.

Q. Now, I turn to page 89. Will you tell us what is shown on that page?

A. Here is the first arrangement I entered in the notes for securing a control bias voltage directly from the signal amplified carrier voltage. All the previous arrangements used a triode rectifier, or a triode detector.

Q. When you say "triode" I think that may be a new word?

A. The triode is the three electrode tube with the grid, and the diode is the two electrode tube exactly the same without the grid. All the previous arrangements had shown a triode tube for obtaining the biasing potential to control the amplifier. And, in all of the preferred arrangements that control was obtained from an amplified carrier voltage.

Now, in this case on page 89 under date of December 17, 1925, I proposed to use, instead, a diode circuit without any batteries of its own to obtain directly from the amplified carrier voltage the necessary biasing potential for control purposes.

Q. When you say "directly" what do you mean to contrast that with?

A. In a triode the output from the tube is not really obtained from the amplified signal. It is obtained from the local battery or power source, whatever it is. And, the signal merely controls the amount of power we receive from the battery. Now, in this diode arrangement, the diode doesn't have a control grid in it like a triode. So, the diode is not an amplifier. It does not rely on a local source of power. Therefore, the output from the diode, whatever it is, is merely a different form of the signal energy that is fed into the diode. It is obtained directly from the signal power that is fed to the diode.

Q. I notice in this diagram on page 89 under the date of December 17th that within that little circle at the top left of the page there appear to be three elements.

A. Yes, I should have explained that. There were at that time no diodes on the market for use in these amplifier and detector circuits because the triode was universally used. Therefore, whenever anyone wanted to experiment with a diode he followed the practice of connecting two of the electrodes of a triode together so that they behaved in effect like one electrode, and then the triode tube could be used as a diode. That was an ordinary way of getting the diode if you wanted it.

Q. How is that shown in this diagram on page 89?

A. On the upper left corner of that page the triode symbol has at the top a horizontal line which is conventional for the plate or anode.

Q. That is within the circle?

A. Yes, just within the circle. It has across the middle a zig-zag line which is a conventional indication of the grid. Sometimes you use a dotted line, too. But, either one indicates the same thing. It indicates the control

grid in the tube. Then, the lower horizontal line within the circle is the cathode or filament in the tube.

Now, in this diagram the upper two symbols within the circle are connected outside by a line which goes up from the plate, and then over to the left, and then down, and then into the grid. By connecting the grid and the plate together we obtain from the triode a device which is really a diode, because the grid and plate no longer behave as separate electrodes.

Q. Under that diagram I notice an expression which says, "To bias grids (through filter);" what does that mean?

A. That connection is the route through which I was planning to deliver from this diode rectifier a rectified potential to control the amplifier. Now, the potential at the diode tube is complicated in that it has what we call several different components.

Any diode rectifier like this develops from an alternating voltage like the signal carrier, develops a direct current potential. In this case a negative potential. And, that potential is developed across a resistance.

In this diagram the resistance is a zig-zag line at the bottom of the diagram directly below the tube, and it is marked 106 ohms.

Q. It has a little symbol there?

A. Yes.

Q. Does that mean ohms?

A. The Greek letter Omega is the symbol we use for ohms. Now, that high resistance is, by the connection shown around it, included in the diode circuit. Then, across that resistance appears this negative direct current potential. But, at the same time—

Q. (Interrupting): The one you want to use for control purposes?

A. Yes. But, at the same time there appear across

this resistance the carrier voltage which we apply to the diode. And, also, the modulation voltage in accordance with the modulation present in the signal. So that expression, "through filter" means that I immediately appreciated we would have to filter out these extraneous components before applying this potential to the amplifier to control the amplification.

Q. When you say "extraneous components," now, you mean the part that corresponds to the high frequency carrier and the part that corresponds to the modulation frequency?

A. Yes, all except the direct current potential.

Q. Now, what do those curves to the right of that diagram mean?

A. They are curves showing the operating characteristics of a diode. Perhaps I don't need to describe the curves in detail, but their significance is this; that long wavy line right in the middle of the page is a sine wave. Well, alternating voltages have a sine wave form. And that was intended to indicate just one cycle of the carrier voltage applied to the diode. And, it is drawn on the diagram in such a size that the peak value of that voltage is 18 volts. And the indication is that it would build up somewhere around 10 volts rectified potential in that resistance under the diode.

Q. I notice it says just to the right of that curve in parentheses, among other things, "10 volts bias." What does that mean?

A. That was the value of the rectified potential that I intended to develop in the diode rectifier circuit for controlling the amplification.

Q. Also just under that it says "Complete cut-off of amplifier obtained at 10 volts A. C. (R. F.) on rectifier tube, so design A. F. detector to operate on 10 volts max. and regulate A. F. amplifier accordingly".

What does that mean?

A. Mostly that refers to an unusual design required for the signal detector in the arrangement proposed in the middle of the page. The first part, however, means that the maximum signal voltage I expected to receive at the diode rectifier circuit was about 10 volts. The reason I did not expect any greater signal was that the control of the amplification would hold the signal within that limit.

Q. You mean if it ever tended to go above it the automatic control would hold it down?

A. Yes.

Q. I think you have already said that a fraction of one volt was the customary voltage in the detector; is that right?

A. Yes.

Q. Just below that part which I have just quoted there is some more circuits. Will you tell us what they show?

A. Tube No. 5 is transplanted from the fragmentary circuit at the top of the page, in a similar environment. That is, tube No. 5 of the diode rectifier, and in this diagram on the middle of the page, are the same associated circuit elements to make it perform in the way I just described.

The diode rectifier circuit in this diagram is used only for control purposes. The tube No. 6 performs the ordinary detector function in the receiver. Tube No. 7 is the audio-frequency amplifier for building up the signal output to a sufficient strength to operate the loudspeaker.

At the bottom of this diagram we see the word "bias" and an arrow. That is the connection which was intended to go back to the carrier amplifier to control the amplification.

Now, tubes 1, 2 and 3 are not shown in this diagram

on page 89 because they were to be arranged in this proposal in the same manner that they are in the diagrams at pages 86 and 88.

Q. I notice somewhat below that diagram we have a label which says "grid volts (approx.)" and then a series of numbers. Do they have the same significance there as you have previously explained in connection with the other diagrams, particularly the one on page 88?

A. Yes.

Q. Well, now, will you turn to page 90 and tell us what that shows with respect to your development of an automatic volume control system?

A. The label on this entry is "differential cut-off for control."

Q. That is under date of December 18th?

A. 1925, yes.

Q. 1925?

A. The fragmentary diagram at the bottom is a circuit arrangement I was planning to try out to obtain a greater amount of control of the amplification in the carrier amplifier in this receiver I was planning to build. The greater amount of control was to be obtained by using two tubes at the same stage and using one of them to oppose the effect of the other under certain conditions. When I built the receiver, I provided an extra vacuum tube socket in this stage for this purpose, but I did not finally use it and I doubt if I even tried it.

Q. Then is that note continued over on to page 91?

A. No. Page 91 deals with the characteristics we might desire in the filter mentioned under the upper left-hand diagram on page 89. This filter was unusual in some ways, but had, as its essential properties, the capability of passing this direct current potential which we wanted for control purposes and not passing the modulation component and the carrier frequency component which were undesired in the control circuit.

Q. I notice a second entry on that page under December 18th. What does that refer to?

A. That is a fragmentary diagram relating to the principal entry on page 90 which I just mentioned, and it shows how to connect back from the detector to this differential control stage.

Q. And is that continued over on page 92? I notice it says at the top of that page "December 18th, 1925 (con.)"?

A. Yes. That is a continuation of the same entry.

Q. Well, now, will you tell us what page 93 shows?

A. These were further suggestions for use in this differential control method.

Q. Now, what did you do next with reference to your automatic volume control system?

A. On December 19, 1925, which was a Saturday, the Christmas holidays started, and I went home from Johns Hopkins University dormitory where I was living to my home which was then in Washington, D. C. Immediately I started work on this receiver which I had been planning to get an experimental test on automatic volume control. I was prepared to start building this receiver immediately because I had obtained the necessary parts aside from small parts that I ordinarily kept on hand at home.

For example, each of the units was planned to be enclosed in a large brass box, and I had already obtained these boxes and I had on hand the necessary condensers and the necessary parts for the construction of this receiver.

Q. Well, now, will you tell us exactly what you did in order to build that receiver?

A. I worked on it steadily all the time I could for about a week, and during that time I completed the assembly of the units and connected them together, and I had no trouble operating them to receive a signal.

Now, the general arrangement of the receiver was like page 88, the large diagram on that page. Then, after operating the receiver to receive signals without paying any attention at first to obtain the automatic control, I modified the detector circuit in accordance with this diagram in the manner required to obtain this automatic volume control. At that point I had a good deal of trouble. The circuit arrangement on that page, while it looked all right on paper, proved to be difficult to design and adjust.

Q. You say it worked all right without the automatic volume control?

A. Yes. I could receive signals on the receiver, but then when I went to adjusting this automatic control to get the new type of operation is when I had the difficulties.

Q. Well, that is the form as shown on page 88, is it?

A. Yes.

Q. Well, what were those difficulties, Mr. Wheeler?

A. The triode detector from which I was trying to get the bias potential for the control proved to be very critical when used for this purpose. I did not have very good apparatus at home and only a limited amount of testing equipment, so I found it impossible to get satisfactory operation from this circuit. I could not tell exactly where the difficulty was, except that the battery voltages and the resistance values in the circuit, as well as the conditions in the tube, apparently had to be proportioned more critically than I could with my limited amount of equipment, and the limited amount of time that I could spend on it during the holidays.

Q. Well, what did you do when you had this trouble?

A. As soon as I ran into these difficulties I looked around for some different circuit I could use which would

get around these difficulties. I had visions of spending the entire holidays trying to make this one circuit work, and, perhaps, not succeeding. So, it was then that it occurred to me to use the proposal of page 89, December 17, which is a few days earlier, because that proposal did not involve the critical relationships. It was unusual, so I had not immediately put it in the receiver, even though I had entered it in the notebook, but after having this trouble I decided it was worth trying.

Q. Did it work?

A. I did not use exactly the arrangement on page 89, but instead I built on that arrangement to secure the circuits shown at the top of page 94. I am not sure what day I devised those circuits, because I think that they were entered in the book after they were put in the set, and I probably worked them out first on scratch paper. But, this arrangement was devised to have the advantages of the page 89 circuit of December 17th, and other advantages at the same time.

The circuit that I was originally building in the receiver had just one detector tube used for both detection of the signal and obtaining the biasing potential for the control. Whereas, the arrangement on page 89 had separate tubes for this purpose. So, the arrangement I finally devised was one to incorporate both of these advantages; that is, first the advantage of using the diode, which was not critical, and using it in a manner suggested on page 89. And, secondly, the advantage of having one tube serve these two purposes; the detection of the signal and the development of this biasing potential.

Now, getting all of these functions in the same tube, and in the same circuit, involved some unusual features in the circuit and the entry at the top of page 94 was intended to explain these features.

Q. Did you actually incorporate the circuit as shown at the top of page 94 in this receiver that you had built at your home?

A. Yes, that was operating by that date, January 2nd, 1926, in the receiver. And, I had no trouble getting that arrangement to operate.

Q. Have you that actual apparatus?

A. Yes. That is the Washington receiver I referred to previously, and is over here on the table.

Q. Now, will you refer to that actual apparatus, which has been marked in this case as Exhibit No. 2, and point out to us these various matters that you have been talking about that are used for automatic volume control?

A. Yes (stepping over to the table).

Q. May I interrupt just a moment?

A. Yes.

Mr. Adams: Your Honor, there is a matter that may lead to some confusion here with reference to the numbers on these exhibits. There has been some testimony corroborative of Mr. Wheeler which has been stipulated between the parties that may be introduced in this case as given in the case in Wilmington. In Wilmington this particular exhibit was referred to as Exhibit 19, and, hence, that testimony refers to it as 19. There are other exhibits which have the same confusion about them. I was wondering whether it wouldn't be simpler to refer to the exhibits in this case by the same number that they are referred to in that stipulated testimony.

The Court: I haven't any objection to it.

Mr. Adams: Any objection, Mr. Darby?

Mr. Darby: None.

Mr. Adams: Then we could refer to this as Exhibit 19, and we will make the appropriate changes on the tags and in the record.

A. When referring to this receiver we may consider the units to be numbered from the left, and there are seven units. Now, the first four units, No. 1 to No. 4, are the units which are involved in amplifying the modulated carrier signal. The first unit is not really an amplifier. It is an oscillator which is a necessary part of a super-heterodyne receiver. But, units 2, 3, and 4 are carrier amplifier units.

Q. When you mention units, Mr. Wheeler, is each unit mounted on its own separate board, and then all of the separate boards mounted on a larger base board?

A. Yes.

Q. Is that right?

A. Yes. Now, the fifth unit is the one which includes the detector circuit or the rectifier circuit of the receiver. Excuse me; the second, third, fourth and fifth units are the amplifier units; and the sixth unit is the one which includes the detector and rectifier circuit.

The seventh unit, which has two tubes, is the audio-frequency amplifier, which was just like any audio-amplifier. At the back of the last or seventh unit is a telephone jack in which the loud speaker would be plugged.

Now, the purpose of the control was to regulate the amount of amplification in the carrier amplifier. I did not regulate every amplifier stage, but only the second amplifier stage which is on unit No. 3.

Q. Can you point to the wire over which the control potential went to that stage?

A. Yes. Just in front of the units there are four heavy wires enclosed in yellow insulated tubing, and one of those wires which is nearest the front of the set is the one by which the biasing potential was conducted to the second amplifier stage on the third unit.

Now, in order to obtain this biasing potential we have

on the sixth unit, another tube just like the others, but which was connected for operation in a diode rectifier circuit rather than as an amplifier. Following this wire on the front, which I can refer to as the direct current connection for the control, we see that wire comes from a point on the last unit. But, the connections are so arranged that that wire obtains the biasing potential from the next to the last unit, on which the rectifier circuit is located.

The path of that connection from the rectifier tube is associated with two resistance units which are little tubular units mounted in clips on the sixth of the units in the receiver. The tube is actually a triode tube on the sixth unit, but the grid and plate terminals are connected together so that the tube behaves as a diode.

Do you wish any further details about those connections?

Q. Under these two resistors to which you have referred there is another piece of apparatus. Will you tell us what that is?

A. That is a square bakelite unit with two terminals and that is a small condenser. That is the condenser which is associated with the diode in the rectifier circuit.

Q. Now which of these resistors—or where is the resistor across which the control potential is built up?

A. On the sixth unit, the right-hand one of the two little tubular resistors to which I pointed before.

Q. What is the value of that resistor, Mr. Wheeler?

A. One-tenth megohm.

Q. Now, where is the filter about which you spoke when you were describing the circuits as shown in your notebook, which was used to filter out the carrier frequency and the modulation frequencies from the path back to the tube that was to be controlled?

A. That filter includes several resistors or resistance units and condensers. It includes first the left-hand one of the two tubular resistances on the sixth unit. Then a large or moderately large rectangular bakelite condenser on the right-hand front corner of the seventh unit. Those two elements together were used to filter out the carrier frequency fluctuations of the voltage from the rectifier.

Then there is another tubular resistance toward the front of the seventh unit and there is a large condenser in a metal box which is located on the main base just in front of the third unit. That resistance and that condenser form the filter which I call the time constant filter for removing the modulation or audio-frequency fluctuations from the biasing potential.

Q. You have referred to the audio-frequency amplifier. How is that connected to the detector?

A. That is connected ahead of the second part of the filter. That is, it is connected between the two parts of the filters that I mentioned. The reason for that was that the audio-frequency amplifier is not supposed to receive the carrier frequency fluctuations but it must receive the modulation or audio-frequency component from the detector. Therefore, the rectified voltage from the detector was first subjected to the filter which removed the carrier frequency fluctuations and was then conducted over to the audio-amplifier.

Q. What other parts—can you point them out?

A. On the seventh unit there is a small bakelite base with a clip which would be capable of holding two tubular resistances. However, there is only one resistance in that clip mounting.

Now, the right-hand front terminal on that small bakelite base is the point from which the modulation frequency voltage was conducted away from the filtering

circuit and it was conducted through the small condenser which is mounted in the middle of the same bakelite base. From there it was conducted to the grid of the first audio-amplifier tube which is the audio tube toward the front of the set as distinguished from the second one toward the back of the set.

Q. I notice on the front of the set a meter, labelled a "Weston voltmeter." Will you tell us what that is and what it does in this set?

A. That is connected with an operation in this receiver which I haven't mentioned and was used to aid in tuning the receiver to the signal that it was desired to receive. This meter is really a sensitive meter which is connected to indicate the amount of current through the amplifier tube on the third unit which was used to control the amplification. Since the meter is connected in this position, it is sensitive to the changes in the amount of control of that amplifier. The meter indicates the relative amount of amplification in that stage which is being obtained on any particular signal that is tuned in.

Now, the receiver is exactly in tune with the signal when there is a minimum amount of amplification. That may sound like an indirect statement, but when the signal is exactly tuned in the tuning circuits are most sensitive to the signal and the amplifier has to do the least amount of work.

So, when the receiver was tuned in, this meter would indicate the minimum amount of current in that controlled tube and it served as a very handy indication to show when the receiver was properly tuned.

Q. I show you a diagram entitled "Wheeler's Washington receiver" and ask you whether that shows diagrammatically the receiver which you have just described?

A. It does.

Mr. Adams: I offer that in evidence as Plaintiff's Exhibit 20.

The Court: Mr. Darby, any objection?

Mr. Darby: Oh, no objection. We have a copy of that, haven't we?

Mr. Adams: Yes, I think so. At least I will give you one if you haven't.

The Court: It will be received.

Mr. Darby: What I meant to say, it is the same diagram you gave us in connection with these photostats.

Q. (By Mr. Adams): I have here another diagram entitled "Wheeler's Washington receiver simplified diagram." Is that a correct diagram of the receiver that you have just described?

A. Yes.

Mr. Adams: I ask that that be marked and offered in evidence as Plaintiff's Exhibit 21.

(The documents referred to were thereupon marked as Plaintiff's Exhibits 20 and 21).

The Court: If there is no objection, it will be received.

Mr. Adams: Also I have there photographs—I don't believe they were taken by this particular witness; but if Mr. Darby has no objection I will offer them as photographs of this physical receiver which is here in court, Plaintiff's Exhibit 19, and I will offer the photographs as Plaintiff's Exhibits 22 and 23.

(The photographs referred to were thereupon marked as Plaintiff's Exhibits 22 and 23.)

Mr. Darby: I have no real objection to them. I don't see that it adds much to the record. You have the apparatus itself, and you have the wiring diagrams, and in so far as they are relevant to this it is limited to the wiring itself. I don't know that it adds anything to

the record. If you have any particular reason for having it in, I won't object to it.

Mr. Adams: The most important reason, I think, is one of convenience in referring to it for other purposes, instead of taking the covers off the apparatus.

The Court: It may be received.

Q. (By Mr. Adams): Now, Mr. Wheeler, did you demonstrate this apparatus, Exhibit 19, to anybody at or about that time?

A. Yes.

Q. Will you tell us about that?

A. As soon as I finished this receiver; that is, about January 2nd, 1926, I demonstrated it to my father, and also to other friends who happened to come in who were interested.

Now, the following day, January 3rd, 1926, we had a social gathering at the house, at my home. There were present several of my associates at Johns Hopkins University who were familiar with the technical side of radio. Those to whom I refer are those whose names appear just below the middle of page 94, namely, Walter A. MacNair, F. M. Defandorf, and V. E. Whitman.

Now, in the evening of January 3rd, 1926 I showed them the operation of this receiver in some detail. I showed them how the automatic volume control operated, and we received a number of different stations. Then I made this notation in the notebook, "Demonstration of audiostat or amplistat, an eight-tube super-heterodyne, Neutrodyne set with automatic volume regulation." I asked them to sign under that notation as witnesses to the demonstration. This they did.

Q. I notice that that date appears to have been changed from January 3rd, 1925, to January 3rd, 1926?

A. Yes. We made the mistake of entering the 1925 date first, because it was only a few days after the new

year. Then, I think someone in the group discovered the mistake, and we changed it then all over the page.

Q. Now, have you any confirmation of that other than what appears on this page 94 of your notebook?

A. Yes, I have a few entries in my personal diaries.

Q. Will you tell us what they are?

A. On Sunday, January 3rd, 1926, in my diary is an entry mentioning this social gathering we had that evening, and including the names of Whitman, and Defandorf, and MacNair among those present. This entry is followed by the notation, "Supper and radio" referring to the radio demonstration after supper.

Q. Do you find any entry in your diary—

A. (Interrupting): Excuse me, there is another entry on that same page.

Q. All right.

A. "Radio work—demonstrated eight-tube set with audiostat." That is under the same date.

Q. Do you find any entry in your diary as to when you went home for the Christmas holidays from Johns Hopkins?

A. Under December 19, 1925, the notation, "Home after lunch;" then the notation "Started work on set, audiostat feature."

Q. What sort of information was it you practiced to put in your diary? Was it a record of technical advances?

A. Generally not. Generally only fragmentary notes on how I was occupying my time. Just occasionally I made notes about radio, when that was the thing that I was most interested in for a period of time.

Q. Now, at the time of this demonstration to MacNair, Defandorf and Whitman, what did you actually do to demonstrate the operation of the set to them?

A. May I hear the question, please?

(Question read).

A. I am not sure just the order of procedure, but I remembered clearly the things I pointed out as special features in this set. I pointed out that we could tune the receiver first to a local station, such as one in Washington, and then to a distant station, such as Pittsburgh, KDKA, and that there was very little change in the volume of sound from the loudspeaker. Then, there was a particular characteristic of the Pittsburgh station as received in Washington. That is, it was noted for its fading. Fading is the term we use to describe an aimless variation of the signal strength from minute to minute in reception. It is caused by variation of conditions in the atmosphere between the transmitting station and the receiving station.

Now, it happens that KDKA was notorious for its fading as it was received in Washington. So, in order to demonstrate this automatic control in the receiver we tuned in KDKA and we noticed that no fading was in evidence.

Now, just by listening it was hard to tell whether the signal was fading or not, but by watching the meter that I referred to on the set we could see that the amplification was being adjusted; first more amplification and then less amplification automatically, and that indicated to us that the signal was fading in and out, but the automatic control was compensating for this fading. That is, the volume of sound from the loudspeaker was held at about the correct intensity even though the signal strength was fading stronger and weaker continually.

Mr. Adams: Now, I may say, your Honor, that the testimony of Mr. MacNair, Mr. Defandorf and Mr. Whitman is some of the testimony that Mr. Darby has stipulated may be introduced into this case.

The Court: Suppose we take a recess now.

Mr. Adams: Very well.

(A short recess was thereupon taken).

Q. (By Mr. Adams: Before we go further through your notebook, Mr. Wheeler, I want to ask you one question to clarify one point. You told us that when you first built this receiver at your home in Washington you used the three-electrode detector and that when you tried to use that for automatic volume control purposes you found that it was too critical to give you the results without considerable adjustment which you did not have time for. Well, now, would that same criticalness be true when the triode was used merely for signal detection instead of for automatic volume control purposes?

A. No. This critical operation was associated with deriving the direct current biasing potential and it was not associated with the ordinary detecting function of the tube.

Q. Had the triode been used for years previously as a detector in radio receiving sets?

A. Yes.

Q. When it was so used, was this direct current component used for anything in the set?

A. No. It was discarded.

Q. It was present, but discarded?

A. Perhaps was not even developed.

Q. Now, I think that you also said that when you devised your diode with a high resistance for use in connection with production of the potential for automatic volume control purposes, it was free from the defects of the triode; is that right?

A. Yes.

Q. Well, just tell us what the characteristics of this diode were that made it superior to the triode?

A. The first major difference which caused one to use the diode was that it was a non-critical device in this circuit arrangement and did not have the extra batteries, so did not require any critical adjustments of any kind. The high resistance was responsible for that because this high resistance, the way it was connected in the circuit, entirely submerged the individual properties of the diode which was used. Then the circuit became very stable in operation. The biasing potential was developed direct from the carrier voltage through this diode rectifier circuit.

Now, the other major difficulty of the triode was a difficulty which was present in its ordinary function as a signal detector. The triode distorted the signal while performing the detection operation.

Now, the nature of this distortion is a little bit complicated. It is involved in mathematical expressions, but the reason for it is rather simple. The triode detector would not function satisfactorily when operated on a large signal voltage.

Now, all detectors distort the signal more or less when they are operated on a small signal voltage. When I say "small signal voltage" at the detector I don't mean as small as we have at the antenna because it is already amplified quite a little. I mean a signal of the order of a few tenths of one volt. That was the signal that was customary to supply to a triode detector.

Now, I say that all signal detectors cause this distortion when they are operated on a tenth of a volt, or few tenths of a volt signal. Then the question arises how they operated when a stronger signal was applied to them. The triode would not tolerate a very strong signal, because it very quickly overloaded.

Now, when we speak about overloading in a detector we don't mean that the detector breaks or burns out.

We mean that it departs from its normal condition of operation. The signal output from the detector, the audio-frequency output, builds up to a certain level and then will not build up any further. That is what we call overloading in a detector. This overloading in a triode sets in at a fairly small signal voltage, perhaps one or two volts. So, in a triode we had one of two operating conditions, either we had a weak signal, with the distortion that accompanies a weak signal in any detector, or we had a large signal voltage and the distortion which accompanies overloading in the detector. Now, when I went over to the diode I got rid of this overloading.

The diode circuit that I was using did not have this difficulty that was inherent in a triode. I could increase the signal voltage up to ten volts or even more, if I had desired, without any tendency whatever toward overloading in this rectifier circuit. Therefore, the diode removed the overloading distortion which was present in a triode, and enabled us to operate the signal detector at a high signal voltage. The net result of this high signal voltage was that we got away from a distortion which was inherent in prior detector arrangements.

Q. I notice on page 95 of your notebook there is a circuit diagram under the date of January 4th, 1926, and under the circuit diagram it says: "In this set the volume regulation works with 10-20 V on No. 6 grid at R. F. More amplification is needed to supply this voltage (at least) on all stations." Will you tell us the meaning of that?

A. This diagram is one which I made on the train on Monday, the day after the demonstration, and I was making notes of the operation of this receiver and its circuit arrangement. That is the Washington receiver. That notation refers to the unusually large signal voltage applied to the detector which was used because this

diode rectifier circuit operated best at a relatively large signal voltage.

Now, in view of this large signal voltage I had discovered in the operation of the receiver that there was not enough amplification on some of the weakest signals.

Q. What do you mean by "some of the weakest signals"?

A. Signals as far away, perhaps, as Chicago, or even further. There was enough amplification for Pittsburgh, KDKA, and there was plenty of amplification for all the local signals. But, that notation meant that I desired a little more amplification for weak signals like the Pacific Coast, or Chicago, or Mexico City.

Q. Then, I notice further down in that same discussion there is a statement which says: "This would point to advantage of control by more than one tube, although brief tests did not indicate an advantage." What does that mean?

A. I mentioned that in the receiver I only applied this control to one of the amplifier tubes. In the experiments I tried controlling one or two of the amplifier tubes at once, and with the amount of amplification I had in that receiver I found that it was not necessary to control more than one tube. However, the notes on this page, after thinking about the operation of the set and the problems involved, indicated that it would probably be preferable to control two stages instead of only one.

Q. After this demonstration to which you have referred on January 3, 1926, and, by the way, will you tell us very briefly who these people were, that is what their connections were at the time, Mr. MacNair, Mr. Defandorf and Mr. Whitman?

A. Yes. They were three men with whom I had contact at the Johns Hopkins University. Dr. MacNair was

engaged in research work under the famous Dr. R. W. Wood, in the physics department of the University. Defandorf was studying for his doctor's degree in electrical engineering. Whitman was my room-mate in the dormitory, and a close personal friend, who was employed in the Bureau of Standards, and was also studying for his doctor's degree in the physics department at the University. I should have mentioned that Defandorf was employed at the Bureau of Standards, and that both Defandorf and Whitman were commuting between Washington and Baltimore to attend classes in the University.

Q. Do you know where they are now employed?

A. Dr. MacNair is with the Bell Telephone Laboratories; Dr. Defandorf is still with the Bureau of Standards, and Dr. Whitman is with the Folmer Graflex Corporation of Rochester, New York, in photographic work.

Q. You referred to the fact that the meter in this set was used as an aid in tuning. I do not believe you told us exactly why it was necessary to use this meter. Will you do so?

A. Yes. In tuning an ordinary receiver in those days, as we turned the tuning knob there was quite a critical position where the sounds from the loudspeaker would be loudest and that is the position of the tuning knobs where we said we were in tune with the received signal. Now, this automatic volume control tended to wipe out the critical changes of the sound at the loudspeaker, and tended to make the sound from the loudspeaker more nearly the same as we turned the tuning knob. It did not wipe out the desired contrast, but if a man was talking in an ordinary tone of voice, and we turned the tuning knob in this receiver, the loudness of the speech from the loudspeaker did not change very much between the time we were exactly in tune and a little bit off tune. That was quite a difference from other re-

ceivers of that day, because the others had a critical condition of tuning which could easily be determined by the operator. In order to make up for this difficulty of tuning the set exactly, this meter that I referred to was used as a tuning meter. The deflection of the meter could be observed easily, although the volume of sound from the loudspeaker was not changing very much while the tuning knobs were being turned. So, we turned the tuning knob to the position where the meter indicated the least current in the meter. That happened to be the correct condition of tuning the way this meter was connected.

The Court: Is that similar to the principle which they use now that some companies at least call the magic eye?

A. Yes, the magic eye is associated with the circuit in the same way that this meter is, not exactly the same place in the circuit, but it gives the same kind of an indication. Now, as the receiver is tuned in, in these magic eye indicators, the width of the shadow in the eye decreases. That corresponds to a decrease of the current in the meter the way I had the meter connected, and the operation is exactly the same. In fact, that is precisely the purpose of including the magic eye in the receiver.

The Court: As I understand your testimony, prior to the time that you watched this Washington set operate, the major factor in determining whether your receiver was in tune was the volume?

A. Yes.

The Court: And after putting that on, the only way you could detect, or about the only way you could detect whether it was in tune or not was by the clarity or the accuracy of the signals being received?

A. Yes.

The Court: So that by having the meter you had a substitute for what they formerly had of the volume?

A. Yes. You might say that was a disadvantage of this automatic volume control.

The Court: Yes.

A. It made the tuning difficult, so we had to devise this means of overcoming the difficulty. Of course this disadvantage was very small compared with the advantages.

The Court: Well, I think I see the picture, taking a radio set as of that day you would normally determine whether you had it in tune or not by the volume of the signal you were receiving?

A. Yes.

The Court: Well, when you remove that means of determining whether you had it in tune, then the only thing you could do was determine whether you were getting accurate signals?

A. Yes.

The Court: Or an accurate reproduction of what you thought the sounds were on the other end?

A. That is correct. Another thing which made accurate tuning necessary, was the freedom from interference. If the receiver is not tuned accurately you may hear the wrong signal, along with the signal you wish, and this meter gives a very quick and direct indication, when you tune to the signal you are listening to, most accurately.

The Court: Well, it works out the same as if you had somebody playing a piece on one instrument like a piano and they hit the wrong note, you would know that they were off, and the same thing would come here, whether it came from interference or from a blurring of part of the scale?

A. Yes, and to the ordinary operator, especially one not skilled in criticizing the sound of speech and music,

the tuning condition is not very critical as regards the character of the sound. It really required a skilled operator to tune a receiver accurately with this control, unless the meter was present.

The Court: You would have to have somewhat the same type of training as a person has to have in order to tune a violin?

A. Almost.

The Court: The principle is pretty much the same?

A. Yes.

Q. (By Mr. Adams): After this demonstration to these friends at your home, did you use this same set at a later time?

A. Of course it was located at my home, and I spent almost all my time at the University in Baltimore, but almost every week-end I went home and experimented some more with this receiver. I was very much pleased with its general operation, and I was anxious to obtain as much experience as possible with it.

Q. I notice an entry on page 96, under date of January 7, 1926; well, apparently the entry was 1925 and it has been changed to 1926. Will you tell us what that shows, and explain about that change in the date?

A. The date of the entry was 1926, and I first wrote "1925" by mistake, then changed it afterwards. This diagram on the left-hand edge of page 96 is another diagram of some of the circuits of the Washington receiver which I made from memory after I returned to Baltimore. I mentioned that I made the diagram on page 95 on the train. That was on a brief trip to New York to confer with some of the men in the Hazeltine Corporation, and the diagram on page 96 was made after I returned to Baltimore.

Q. Only one thing I wanted to call attention to in connection with that diagram; I notice that one of the

tubes in about the center of the diagram, which is labelled "Det.", apparently has the anode and cathode directly connected together, and in this other diagram to which you referred on page 89, apparently the grid and the anode were connected together. Will you comment on that difference?

A. Those are two different connections which operate the same way in using a triode as a diode. In the December 17th note on page 89, I happened to show the grid and plate connected together. I showed it that way also on page 94, and that is the way the connection is made in the Washington receiver. On pages 95 and 96, where I drew the diagrams from memory, I accidentally showed the other connection, the results being exactly the same.

Q. You spoke of taking a trip to New York at about this time to confer with people at the Hazeltine Corporation. Did you advise them of your work on automatic volume control?

A. Yes. I was very enthusiastic about the results I had obtained in this Washington receiver and I probably mentioned it to everyone I saw who was associated with the Hazeltine Corporation in New York. I remember especially telling Mr. Dreyer about it. He was one of the engineers of about my age with whom I was most closely in contact.

Q. I show you a letter dated December 15, 1925, and ask you to identify that?

A. That is a letter which I wrote to Mr. Dreyer, who I just mentioned, shortly before the Christmas holidays in 1925.

Q. In that letter it states:

> "I *hope* to build the new volume control into a receiver at my home during the holidays *in which case* I may ask you and some of the others to come down and look it over early in January."

Now, did you ask them to come down?

A. Yes. I urged them to come and see this receiver in operation as soon as they could.

Q. Did Mr. Dreyer reply to that letter?

A. Yes, I have here his reply dated December 24th, 1925, on the letterhead of the Hazeltine Corporation. I received that reply shortly after that date.

Q. I notice on page 2 of that reply Mr. Dreyer says:

> "I hope that you are successful in accomplishing your desire with but one additional tube and would be very glad indeed to visit you during January if you are successful."

What does he refer to there when he says "with but one additional tube"?

A. In talking about this automatic volume control with Dreyer in the summer of 1925 I think we were both impressed with the probable need of several additional tubes, and tubes were an expensive part of the receiver. Now, the feature of my letter of December 15th to which he refers was that I then thought it would take only about one additional tube in the receiver to obtain this control operation.

Q. As you finally built the receiver, did you use one additional tube?

A. It is a little hard to compare the receiver I made with the existing receivers of that time because I used the super-heterodyne and also I used this diode rectifier circuit, which did not perform the amplifying function of the usual detector. However, there were no tubes in the receiver finally which were used or added exclusively for automatic volume control. All the tubes were used for the normal signal operation.

Q. Did Mr. Dreyer ever come to Washington to look at your receiver?

A. A little later he did, in April, 1926.

Mr. Adams: May I offer in evidence the letter from Wheeler to Dreyer dated December 15, 1925, as Plaintiff's Exhibit 24-A, and Dreyer's reply dated December 24, 1925, as Plaintiff's Exhibit 24-B?

The Court: They will be received.

(The letters above referred to were thereupon marked Plaintiff's Exhibits 24-A and 24-B.)

Q. (By Mr. Adams): When did Mr. Dreyer come to Washington for this demonstration, Mr. Wheeler?

A. The early part of April, 1926.

Q. Do you find any entry in your notebook on that subject?

A. Yes. On page 94, on the right-hand margin, is a notation "Demonstrated to me on 4/5/26 J. F. Dreyer, Jr." That is a note which Dreyer made on that page on the occasion of this visit to Washington when I showed him the operation of this receiver.

Q. What do those diagrams actually show? Will you tell us briefly?

A. They show the various functions of the diode rectifier circuit which I had incorporated in this receiver. The diagram at the top of the page shows all the elements of the rectifier circuit. Then the second, third and fourth diagrams are partial diagrams which I used to illustrate, by the shorthand of our circuit symbols, the various functions of the circuit elements in this rectifier circuit. The second diagram on the page shows how the carrier frequency component of the signal was removed from the rectified output of the detector. The third diagram shows how the modulation component of the audio-frequency component was passed on to another tube for amplification and also was removed from the connection back to control the amplification. The fourth diagram shows how the direct current potential

was passed on without obstruction to control the amplification.

Q. I show you a letter dated April 14, 1926, signed by John F. Dreyer, Jr., and ask whether you recognize that signature?

A. I do. That is the signature of Dreyer whom I mentioned.

Mr. Adams: I may say that Mr. Dreyer's stipulated testimony also identifies this.

The Court: All right.

Mr. Adams: And I offer, therefore, this letter in evidence as Plaintiff's Exhibit 25.

The Court: It will be received.

(The letter above referred to was thereupon marked Plaintiff's Exhibit 25.)

Q. (By Mr. Adams): In this letter—oh, by the way, I may ask you who is Mr. R. T. Pierson to whom this letter is addressed?

A. He was the president of the Hazeltine Corporation.

Q. In this letter it states:

> "I was very much impressed by the operation of this device and believe that it would be advisable to submit it to the licensees. This could best be done, I think, by inviting Mr. Wheeler to one of the engineering meetings I planned and have him tell them at that time."

Did Mr. Pierson ask you to do that?

A. First he asked me to bring this Washington receiver to the laboratory which was then located at Hoboken, New Jersey. I was hesitant about doing this, because the receiver was so constructed that its operation might be detrimentally affected by moving it. However, in the latter part of 1936—excuse me—1926—they did invite me to attend one of these engineering meetings and

to describe this automatic volume control to the engineers of the licensee manufacturing companies.

Q. I show you a letter dated May 4th, 1926, addressed to you from R. T. Pierson, and ask you whether you can identify that (handing document to witness)?

A. This is a letter which I received from Mr. Pierson asking me to bring the Washington receiver to the Hazeltine Laboratories for further study.

Mr. Adams: I offer that in evidence as Plaintiff's Exhibit 4.

Mr. Darby: No objection.

(The document above referred to was thereupon marked Plaintiff's Exhibit No. 4.)

Q. I show you a letter dated May 17th, 1926, addressed to Mr. R. T. Pierson and signed by Harold A. Wheeler, and ask you whether you can identify that (handing document to witness)?

A. That is my reply to Mr. Pierson's letter.

Q. In that letter you state: "I suggest that I build the design into a three or four stage shielded Neutrodyne receiver already constructed, or still better in the process of construction at the Stromberg-Carlson or Howard factories, since the latter procedure would obviate some of the reconstruction difficulties." What do you refer to there?

A. I had just mentioned in the letter that the receiver was in a temporary form since it was built up in such short time, and that instead of bringing my receiver to the laboratory it would be better to build the automatic volume control into a standard receiver made by one of the licensees.

Mr. Adams: I offer that letter in evidence as Plaintiff's Exhibit 5.

(The document above referred to was thereupon marked Plaintiff's Exhibit No. 5.)

Q. Did you do anything toward building the receiver into a commercial model, commercial apparatus?

A. Yes. About the end of July, 1926, I made a trip to the Stromberg-Carlson factory in Rochester. There I gave the circuit arrangement of the automatic volume control to the Stromberg-Carlson engineers, Mr. Graham and Mr. Levy. Immediately afterwards they built this circuit into one of their standard receivers, and sent the receiver to the Hazeltine Laboratories for testing.

Q. Have you that receiver?

A. Yes. It is the receiver in the large cabinet which is sitting on the floor here (indicating).

Mr. Adams: Mr. Wheeler in his previous testimony identified this same receiver. That, I believe, is at pages 33 to 42. At that time the receiver was offered in evidence as Exhibit 3. Because of the fact that it is referred to by these other witnesses I should like to change its identification to Exhibit 14, because that is the way in which it is identified in those other depositions.

The Court: You may do so.

Mr. Adams: Also, I should like to submit for convenience in the record photographs of that apparatus as Plaintiff's Exhibits 14-A and 15.

(The two photographs above referred to were thereupon marked Plaintiff's Exhibits 14-A and 15, respectively.)

The Court: They may be received.

Q. I show you Plaintiff's Exhibit 15 and ask you to state what it is a photograph of (handing document to witness)?

A. That is a photograph of a small Bakelite panel within the receiver which I just pointed to.

Q. There appear to be some words shown in that photograph. Can you tell me what they are?

A. There is an inscription scratched on this Bakelite panel as follows: "Demonstrated August 11th, '26. W. A. M., H. A. W., M. L. L." That inscription was marked on this Bakelite panel on the occasion of demonstration of that receiver at the Hazeltine Laboratories in Hoboken. The first part of the inscription was put there by Mr. MacDonald, followed by his initials, after which I added my initials, and Mr. Levy of the Stromberg-Carlson Company added his initials, M. L. L.

Q. Now, I show you a circuit diagram labelled "Stromberg-Carlson receiver simplified diagram" and ask you whether that is a correct diagram of the circuits of this Stromberg-Carlson receiver?

A. It is.

Mr. Adams: I offer that in evidence as Plaintiff's Exhibit 14-B.

Mr. Darby: No objection.

The Court: Received.

(The document above referred to was thereupon marked Plaintiff's Exhibit No. 14-B.)

Q. On this simplified diagram of the Stromberg-Carlson receiver, will you just point out briefly the tube which furnishes the potential for automatic volume control?

A. Yes. There are six tubes indicated by circles on this receiver. The fourth one from the left is the diode in the rectifier circuit.

Q. Is that a diode made by connecting together two elements of the triode?

A. Yes.

Q. Now, can you tell us what tubes have their amplification controlled by the potential which is derived from this diode circuit?

A. Just one tube, the first one on the left.

Q. And can you tell us what is the wire over which this controlled potential flows?

A. That is the lowest horizontal line in the diagram.

Mr. Adams: Now, I may say to your Honor that part of the testimony which was stipulated as the testimony of an engineer of the Stromberg-Carlson Company named Levy, who made some record of this work in his notebook, and the particular pages of that notebook to which he referred were offered in evidence and are part of the stipulation. I do not have the original notebook, but I have copies of those pages. I understand that Mr. Darby has no objection to my referring to copies of those pages.

Q. (By Mr. Adams): I show you, Mr. Wheeler, some photostats of sheets labelled—well, the whole thing is labelled "Plaintiff's Exhibit No. 16, H. C. Mahaffy, Jr., Clerk," and one of the pages is numbered 58, another is numbered 59, and another is numbered 60. Can you tell me whether they show this automatic volume control system about which you have been talking?

A. Page 59, entitled "Wheeler's audiostat," is a diagram of the parts of the receiver which have to be modified in order to put this automatic volume control in a standard receiver.

Q. Did you draw that diagram?

A. No, I drew on a loose sheet of paper a diagram similar to this one and gave it to Mr. Levy on the occasion of my trip to the Stromberg-Carlson factory late in July, 1926.

Mr. Adams: I will offer those sheets to which Mr. Wheeler has referred as Plaintiff's Exhibit 16.

Mr. Darby: No objection.

The Court: Received.

(The documents above referred to were thereupon marked Plaintiff's Exhibit No. 16.)

Q. (By Mr. Adams): At the time of the demonstration of this Stromberg-Carlson receiver at the labora-

tories of the Hazeltine Corporation, did you make any note of the circuits in your own notebook?

A. Yes, I did; on page 75 of my notebook, No. 8.

Q. What did you put on that page?

A. On August 11th, 1926, I wrote the following entry: "Audiostat demonstration. Set assembled by M. L. Levy, Stromberg-Carlson laboratory, Rochester. Design to Mr. Graham there August 2, 1926. First operation at my home, Washington, D. C., December, 1925. This set demonstrated at Hazeltine Laboratory August 10-11, 1926." Below this inscription is a partial diagram of a radio receiver showing the circuit involved in the automatic volume control.

Q. Underneath that circuit it says: "Filament of next to last (audio input) two controlled to regulate volume"; what does that mean?

A. In addition to the automatic volume control, a receiver has to have some knob which the user can turn to determine whether the sound from the loudspeaker is loud or soft. In this receiver one of the audio-amplifier tubes was subjected to a control by an extra knob for this purpose. The result of this control is that the user can determine whether all of the signals will be reproduced with a loud volume, or all with a soft volume. The automatic control merely assures that all of the signals will come in with nearly the same volume.

Q. Whatever volume the operator has selected by means of this knob?

A. Yes.

Q. Now, you referred some time back to disclosing this system to the engineers of the companies licensed by the Hazeltine Corporation; did you do that?

A. Yes.

Q. When was that?

A. At their meeting in New York City on August 19, 1926.

Q. I show you two mimeographed sheets entitled "Minutes of the August meeting of the I. R. M. Engineers," and ask you whether you can identify that?

A. Yes. This is a copy of the minutes of the meeting I just mentioned. The licensees' engineers are referred to as the "I. R. M. Engineers," because the licensee manufacturers were associated with an organization called the "Independent Radio Manufacturers."

Mr. Adams: I offer that in evidence as Plaintiff's Exhibit 13.

Q. (By Mr. Adams): At the end of this, namely, on the bottom of page 2, there is a list of names under the heading of "Those present at the meeting were:" Will you tell me who each of those persons was?

A. Mr. Binns was treasurer of the Hazeltine Corporation, and still is. Mr. Clement was chief engineer of the Fada Company manufacturing radio receivers.

Q. And is he still?

A. No, Mr. Clement is now in a high executive position in the R. C. A. Manufacturing Company of Camden, New Jersey. Mr. H. Dreyer was a brother of the Mr. J. F. Dreyer I have mentioned, and he was then an engineer with Freed-Eisemann.

Q. Was he an engineer interested in circuits?

A. No, he was a production engineer.

Q. Well, I might ask you about Mr. Clement. Was he interested in circuit designs?

A. Yes, he was very much interested in all phases of receiver manufacture, including the circuit design.

Q. How about Mr. Graham?

A. Mr. Graham was a radio engineer with Stromberg-Carlson. Mr. Johnson was one of the engineers in our laboratory.

Q. And Mr. Graham, I understand, is now with Hygrade Sylvania Tube Corporation; is that right?

A. Yes. Mr. Johnson was then one of the engineers in our laboratory and is now the chief radio engineer of Stewart-Warner. Mr. Loeser was an engineer of Eagle Radio Company.

Q. Where were they located?

A. In New Jersey, I think in Elizabeth. Mr. MacDonald was the chief engineer of Hazeltine Corporation. Mr. Manson—

Q. He is still there, isn't he?

A. He has a different title now, but he is now vice-president in charge of engineering. I mean Mr. MacDonald is.

Q. Yes.

A. Mr. Manson was then and still is the chief engineer of Stromberg-Carlson. Mr. Marsten was an engineer of Freed-Eisemann.

Q. Was he a designing circuit engineer?

A. No. He was more interested in production of receivers. Mr. Miessner was an engineer of the Garod Corporation.

Q. Was his special interest circuits?

A. He was specializing in one particular problem in the receiver, namely, the problem of operating the receiver from the alternating current lighting circuit. He was not so much interested in anything else in the receiver. Mr. Million was an engineer with the King-Hinners Radio Corporation. Mr. Russ was an executive of the Independent Radio Manufacturers. Mr. Dreyer was an engineer of Amrad. He is now, I believe, with the Crosley Radio Corporation as an engineer. And the last name is mine.

Q. You did not say what Mr. Million is doing now. Do you know?

A. I am not sure.

Q. Was he interested in circuits at that time?

A. Yes, very much so.

Q. Now, was this Stromberg-Carlson receiver, or receivers of that type, ever produced in quantities by the Stromberg-Carlson Company?

A. Do you mean with or without automatic volume control?

Q. I mean with your automatic volume control?

A. No.

Q. Immediately following this time, which, as I recall it, was in August of 1926, did they make any sets with automatic volume control?

A. Not excepting one or two more developmental sets in the laboratory. They did not make any for sale.

Q. What was the next set in which you embodied your automatic volume control circuit?

A. In the summer of 1927 I spent some time at the Howard Radio Company in Chicago and embodied the automatic volume control in a modification of one of their commercial receivers.

Q. Will you tell us something about that, Mr. Wheeler? What sort of a receiver was that, and what were the circumstances under which you embodied it in that receiver?

A. I had met Mr. Howard and some of his engineers incidentally on a trip to Chicago in the middle of 1926 and I had mentioned to them the unusual advantages of this automatic volume control, suggesting that they might want to put it in one of their receivers.

About the middle, or, I should say, I think, in the spring of 1927, they became further interested and arranged for me to spend some time at the Howard Radio Company in the summer of 1927 for this purpose. I took a design of one of the higher grade receivers then being manufactured by the Howard Radio Company and I modified this design to incorporate the automatic volume control with the diode rectifier circuit.

Q. When you say higher grade, what do you mean?

A. One of the higher priced range. I think this receiver was sold by the company as a seven-tube receiver. It also had some additional tubes in the power supply apparatus, but there were seven tubes active in the main part of the receiver. That was a very high grade set for those days.

Q. Well, what did it sell for, do you know?

A. Around $200.

Q. Go ahead.

A. This receiver was a Neutrodyne receiver of the type then common. I mention that because the various designs of receivers we have been using over a period of years are easily classified into different types, and this is one definite type which was then common. In order to improve the performance of the receiver generally, at the same time, we added the automatic volume control. I think we built this up to a nine-tube receiver, and, at the same time, incorporated the automatic volume control.

Q. When was this?

A. In the summer of 1927.

The Court: You may come back at two o'clock. Adjourn until two o'clock.

(Whereupon a recess was taken until 2 o'clock P. M. of the same day, Thursday, October 26, 1939.)

Detroit, Michigan,
Thursday, October 26, 1939,
2 o'clock P. M.

Court met pursuant to recess.

Parties present same as before.

The Court: You may proceed.

HAROLD A. WHEELER, was thereupon recalled as a witness herein, and having been previously duly sworn, testified further as follows:

Direct Examination (Continued)

By Mr. Adams:

Q. When we adjourned for lunch Mr. Wheeler was testifying about his design or redesign of a Howard set to incorporate his system of automatic volume control. Will you continue with that, Mr. Wheeler?

A. In the latter part of the summer of 1927 we finished redesigning this Howard receiver, and it was then a very high class receiver as receivers went in those days. Not very many of these receivers were manufactured by the company; perhaps half a dozen, because they were in such a high priced class. The final receiver was put in an elaborate cabinet and was reputed to have sold at $3,000 or so. Very few were made and sold. These that were sold were made up in the fall of 1927.

Q. Now, did you at about that time disclose your system of automatic volume control to the engineers in the industry generally?

A. Yes.

Q. Tell us about that?

A. Early in November, 1927, I spoke to the New York meeting of the Institute of Radio Engineers and described this system of automatic volume control.

Q. I show you a copy of the proceedings of the Institute of Radio Engineers dated January, 1928, and direct your attention particularly to the article headed, "Automatic Volume Control for Radio Receiving Sets," on pages 30 to 34 inclusive, and ask you whether that is the paper that you delivered at that time (handing booklet to the witness)?

A. It is.

Q. Does that show this diode circuit, automatic volume control system?

A. Yes.

Q. Where?

A. In Figure 2.

Q. Was that a meeting of the Institute which was attended by various engineers in the industry?

A. Yes. I think there were several hundred in attendance.

Mr. Adams: I ask that this be marked as Plaintiff's Exhibit No. 17.

Mr. Darby: No objection.

The Court: It will be received.

(The booklet above referred to was thereupon marked Plaintiff's Exhibit No. 17.)

The Court: May the record show that all of these exhibits that you offer as you go along will be received in evidence unless there is objection made?

Mr. Adams: Very good, your Honor.

Q. Now, what was the first receiver that was sold in quantities, the first commercial receiver, which employed automatic volume control?

A. Of any kind?

Q. Of any kind.

A. In 1928, in the fall, R. C. A. brought out a receiver called the Radiola 64. That was the first commercial receiver to be sold in large quantities with any kind of automatic volume control.

Q. Was that manufactured by the Radio Corporation of America?

A. No. It was manufactured by the Wireless Specialty Apparatus Company, an affiliate of the R. C. A.

Q. Do you know who designed it?

A. The engineers of the General Electric Company and the Westinghouse Company designed the receiver, especially Mr. W. L. Carlson of the General Electric Company, and Mr. G. L. Beers of the Westinghouse.

Q. What sort of a system did they use to derive the potential for automatic volume control?

A. A separate triode rectifier.

Q. Do you know whether that apparatus had sufficient amplification so that they could have used a diode circuit for securing automatic volume control potential?

A. I know it did.

Q. Do you know whether or not in the amplifiers that set used what are called screen grid tubes?

A. It did not.

Q. Did that receiver, the Radiola 64, continue on the market for several years?

A. Only for another year, in 1929, when it was again marketed under the designation Radiola 67.

Q. Was there no such set on the market the following year?

A. In 1930 R. C. A. brought out no receivers having automatic volume control of any kind.

Q. Well, I assume after that they brought out some other sets having automatic volume control; is that right?

A. Yes. Beginning in the latter part of 1931 they did.

Q. Did they use the same sort of system with the triode for securing the automatic volume control potential?

A. There were some receivers with the triode automatic volume control brought out late in 1931. Then I

think it was the following year when they brought out receivers using the diode a.v.c. system.

Q. What was the practice from that time on of the Radio Corporation of America?

A. They discontinued the use of the triode automatic volume control and they have since used the diode arrangement exclusively.

Q. Now, what was the first use in a commercial receiver sold in substantial quantities of your system of automatic volume control, using the diode circuit for securing the control potential?

A. The Philco Model 95, which was brought out in the latter part of 1929.

Q. Will you tell us something about that receiver? Did you design it?

A. I designed the Philco 95 receiver in the spring or early summer of 1929, working in close cooperation with the Philco engineers. I incorporated the diode system of automatic volume control, which I had developed, in this receiver. It was manufactured in the fall of 1929, and after that many of them were sold commercially.

Q. Was it successful?

A. Yes.

Q. Was the automatic volume control system in it successful?

A. Yes.

Q. Do you know what the practice of the Philadelphia Storage Battery Company has been with respect to the kind of automatic volume control system they have used since then?

A. Yes, I do. They have used the diode system in preference to all others.

Q. I show you a circuit diagram entitled "Philco Model 95," and ask you whether that is the circuit of

that Model 95 receiver using your automatic volume control system?

A. It is.

Mr. Adams: I ask that that be marked Plaintiff's Exhibit No. 18.

(The diagram above referred to was thereupon marked Plaintiff's Exhibit No. 18.)

Q. (By Mr. Adams): Will you tell us by reference to that circuit diagram which one of the tubes is the one which forms the part of the diode circuit that you used for securing the automatic volume control potential?

A. Yes. There are six tubes indicated in circles in a row along the top of the diagram. The fourth one, marked "227," has the grid and plate tied together, and that is the diode used in the a.v.c. circuit.

Q. What was the next receiver that you designed, using your system of automatic volume control, that was sold commercially in substantial quantities?

A. The Fada model KA.

Q. I show you a circuit diagram and ask you whether that shows the circuit of that Fada model?

A. It does, and I notice the model numbers on this diagram are 42, 44, 46, 41, 47. The designation "K.A." was a general designation for this group of models.

Q. Will you tell us which one of the tubes on this circuit diagram was in the diode circuit which you used for securing the automatic volume control potential?

A. In the top row of circles indicating tubes, there are seven circles. The middle one, the fourth one, is the diode.

Q. It seems to have a lot of extra marks inside that circle. Will you tell me what they are?

A. On the left-hand side within the circle is a zigzag line representing the grid. On the right-hand side there is a rectangle block representing the plate.

Q. Or anode?

A. Yes. Just between those two symbols is a hook-shaped line representing the cathode, and just under the cathode is, an inverted "V" which represents a hair-pin filament.

Now, in this type of tube the filament itself is not used as the cathode. The filament is used to heat a small metal tube, and that metal tube is the cathode.

Q. Now, I notice that cathode, the indirectly heated cathode, appears to be connected by a continuous line to the anode over on the right, is that correct?

A. Yes; in this receiver that is the connection which was used to employ the triode as a diode.

Mr. Adams: I offer that diagram in evidence as Plaintiff's Exhibit 6.

(The diagram above referred to was thereupon marked Plaintiff's Exhibit 6.)

Q. (By Mr. Adams): This was in what year, Mr. Wheeler?

A. This receiver was designed early in 1930 and was manufactured later the same year.

Q. Some time ago you mentioned the fact that receivers were conveniently grouped into so-called Neutrodynes and super-heterodynes. Of which type were these Philco and Fada sets to which you have referred?

A. They were another type still. They were slightly different from the Neutrodyne sets in that they employed screen grid tubes for amplification instead of just a simple triode with the Neutrodyne principle applied to it. The Neutrodyne and screen grid sets, of this type anyway, fall in a common class which we call "T. R. F.", sets "T. R. F." standing for "tuned radio frequency". The "T. R. F." set as a class is different from the super-heterodyne. The Neutrodyne receiver is one kind of a "T. R. F." set. These receivers I have just been men-

tioning, the Philco and Fada receivers, are "T. R. F." sets with screen grid tubes instead of the Neutrodyne.

Q. What type of set was the Radiola 64; was that a "T. R. F." or a super-heterodyne?

A. A super-heterodyne.

Q. Did the art generally use either one type or the other?

A. Prior to 1929, from about 1923, the art used the Neutrodyne T. R. F. sets almost exclusively.

Q. You say the art used the T. R. F. sets?

A. T. R. F. Neutrodyne.

Q. Did the super-heterodyne come into use at about 1930, generally?

A. Yes.

Q. Prior to that time had it been used by the Radio Corporation of America?

A. Yes.

Q. Well, now, up to this time had there been any sets such as we know them now in automobiles, which are generally referred to as automobile receivers?

A. No, they were very scarce.

Q. Will you tell us something about the advent of the automobile sets?

A. Around the period of 1930 to 1932 there was increasing use of radio receivers in motor cars. The experience with these radio receivers very quickly showed up a severe problem when they tried to put an ordinary receiver into a car and use it while the car was moving. Every time the car would go under a bridge, or under some telephone wires, the signal would become weak, and under certain conditions the signal would become much stronger than normally. This we can regard as a type of fading, although it was not really caused by atmospheric conditions, as the ordinary fading was. It was caused by the motion of the car. This problem in motor

car receivers was very soon appreciated as making it absolutely essential to have automatic volume control in these receivers. Automatic volume control was adapted to motor car receivers almost immediately, and with that improvement they became popular.

Q. Do you know what was the first automobile set to employ automatic volume control?

A. I am not sure. Probably a Philco or an R. C. A. set.

Q. Do you know what kind of automatic volume control was used in these automobile receivers?

A. The Philco Company immediately put into the motor car receivers the same kind of automatic volume control, the diode system, that they had been using in their commercial broadcast receivers for home use. Some other companies tried to employ the triode automatic volume control in their motor car receivers. I think the R. C. A. used the diode system immediately in their motor car receivers.

Q. Now, can you tell us, Mr. Wheeler, about the use of automatic volume control by the manufacturers generally in the industry at about this time? Did they begin to use it in their radio receivers about 1930?

A. Aside from the Radiola 64, the beginning of the use of the automatic volume control by other companies was in 1929. That was the year when my system was adopted by Philco and when the triode automatic volume control was used by some other companies.

Then, during the next few years, let us say from 1929 to 1932, there was a rapid increase in the use of automatic volume control in the better class of receivers. Some companies used my system and others used the triode a.v.c. There was a continuous trend away from the triode system and towards the diode system until by 1935 the diode system of a.v.c. was used exclusively.

Q. Have you prepared a chart which graphically shows the trend in the industry?

A. Yes.

Q. I show you a chart and ask you to tell us briefly what it shows?

A. It is entitled "Commercial use of automatic volume control." This is a chart I have prepared to show approximately the relative use of the diode system and the triode system in radio receivers in the period of 1930 to 1935. The total height of each bar on this diagram represents the total number of models using automatic volume control of any kind. The shaded portion represents the relative number of models using triode a.v.c. and the unshaded portion of each bar represents the relative number of models using diode a.v.c. This shows graphically the increasing use of automatic volume control on all kinds of sets but also the decreasing use of the triode a.v.c. from 1932 on.

Q. I notice that chart goes only to 1935. What has been the history since then?

A. Since that time all excepting the very cheapest sets have used the diode system of a.v.c., and very cheapest sets are the only ones which still get along without any a.v.c.

Q. Of any kind?

A. Yes.

Mr. Adams: I offer that in evidence as Plaintiff's Exhibit 7.

Mr. Darby: I object to that. I think we ought to have a little information as to the source of the information. I temporarily object to it.

The Court: How important is it, anyway?

Mr. Adams: It isn't important as far as actual magnitudes are concerned. It is important only as illustrative of the witness' testimony. It is merely offered as a convenience.

The Court: If it was offered for the purpose of establishing commercial use, it would be inadmissable on the ground that there is no distinction between what you claim to be your invention and the other types of use, would there, and there might be somebody somewhere down the line might get the idea this was an indication of how successful your invention was.

Mr. Adams: Well, maybe I can ask Mr. Wheeler something right on that point.

Q. (By Mr. Adams): This chart shows the increasing use of the diode form of automatic volume control. Do you mean that to be your system of automatic volume control?

A. Yes. The diode a.v.c. is what I consider to be my system, and it is that system which is represented by the diode a.v.c. in this chart.

Q. Were you generally familiar during all of these years with the developments in the industry by the various manufacturers in so far as their form of automatic volume control was concerned?

A. Yes.

Q. Have you recently, or in preparation of this chart, gone through the circuit diagrams of all of the sets manufactured during those years?

A. All that I could find in the standard reference books.

Q. What standard reference books did you consult?

A. The standard reference book for radio receiver circuits in the broadcast field is Rider's Manual, which is published annually. The first volume came out around 1930, and it has been published annually since then. That is the recognized authority.

Q. And did you go through that page by page and examine all the circuit diagrams?

A. Yes.

Q. Is that relied on by the engineers in the industry as giving the correct circuits of the receivers sold in the radio industry?

A. I think so.

Mr. Adams: Now, with that explanation as to the source of Mr. Wheeler's knowledge on this subject, I offer this again in evidence as Plaintiff's Exhibit 7.

Mr. Darby: I have no objection to it now, as to its competency, but I would like to say this at this time, if your Honor will bear in mind that my silence is not acquiescence in the proposition that these circuits that were employed by these men were actually diode tubes. Judge Campbell held they were not, and, of course, the witness has given his opinion, and that is one of the issues before your Honor.

The Court: Yes. Well, let me get this straight. In effect, you claim that you have a monopoly on the use of a diode tube for the purpose of volume control.

Mr. Adams: No, we don't say that, your Honor. We say that prior to Wheeler there was not any use of any form of diode for automatic volume control. He did devise a particular circuit which made it possible to use the diode for automatic volume control. He made certain important changes in the circuits in which the diode was used. And we say that that type of circuit, that diode circuit devised by Wheeler for automatic volume control, has been used. There is no other diode form of automatic volume control that has been used. That is our position.

The easy way, of course, to distinguish, the shortest way to distinguish Wheeler from the other systems is to say "diode versus triode", but that is accurate only if you keep in your mind the fact that it was not merely the diode but was the particular diode circuit devised by Wheeler. The diode was a very old instrumentality itself and had been used many years before in the art.

(The document above referred to was thereupon marked Plaintiff's Exhibit No. 7.)

The Court: All right.

Q. (By Mr. Adams): Now, I wanted to clear up one point, Mr. Wheeler. At the time, or prior to the introduction of this Radiola 64 had there been any commercial sets using automatic volume control of any kind?

A. Only the few sets I mentioned of the Howard Company.

Q. And, now, between the time of the Radiola 64 and the Philco Model 95 which embodied your system, and which I understand is successful, were there any other systems of automatic volume control in commercial receivers?

A. I don't know the exact dates, but about the same time in 1929, about the same time as the Philco receiver, there were some other receivers introduced by other companies using the triode form of a.v.c. Now, I should mention that when I say the triode form of a.v.c., I include some variations which actually used a tetrode or four-electrode tube, but which had the essential characteristics of triode in their operations.

Q. Were those sets successful, do you know that much about them?

A. Quite a number were sold, but they did have some trouble with the triode a.v.c. system.

Q. Now, at this time were there any diodes as such available on the market that you could use in your diode system for automatic volume control?

A. No.

Q. And, when the Philco set was built and the Fada set, I think you pointed out that they made a diode out of the triode so as to use this diode system of automatic volume control, is that right?

A. Yes.

Q. Well, now, as time went on were there any diode tubes introduced specially for automatic volume control circuits?

A. Yes. In the latter part of 1931 the Grigsby-Grunow Company, the makers of the popular Majestic receivers, brought out a special tube for the purpose of diode a.v.c. It was actually a tube having two diodes in one envelope, in one glass bulb, and they called it a duo-diode, or double diode, some such name.

Q. You say with two diodes in one glass bulb. Was that for automatic volume control?

A. Yes.

Q. Did they use two diodes for the automatic volume control?

A. There is a slightly improved operation obtained by using two diodes in what we call full wave rectification, instead of a single diode which gives us only what we call half wave rectification.

As far as the circuits are concerned, each diode individually, I mean either one of these two diodes, would give the results, but using the two together, gave a slight improvement of the result.

Q. Did the Grigsby-Grunow Company manufacture receivers as well as tubes?

A. Yes.

Q. Did they incorporate this tube in their own receivers?

A. Yes.

Q. Prior to that time had they been making receivers using automatic volume control?

A. Yes, they had been using the triode system of automatic volume control in the better class of receivers they had been making.

Q. And what was this date that you say they brought out a special tube to use the diode system?

A. About the fall of 1931.

Q. Were there any other developments of tubes for the purposes of automatic volume control?

A. Shortly after the introduction of this diode tube by the Grigsby Grunow Company, a special diode tube was brought out by R. C. A. called the type 55. That was early in 1932. The type 55 was a little different still. It had in one glass envelope two diodes and a separate triode. One or both of the diodes could be used for automatic volume control. The triode part of the tube was then left over for any additional use you wanted to make of it.

For example, the triode part of the tube was commonly used as the first stage of the audio-amplifier. The obvious purpose of putting these separate tubes in one glass envelope was to save space in the receiver. It happened that the diodes themselves did not require very much space, and this triode didn't require very much space. The main thing which occupied the space was the size of the glass envelope. So, this 55 tube had in one glass envelope two diodes and a separate triode.

Q. Is that what was called a combination tube?

A. It had various names; combination tube, or multi-unit tube. This particular one I think was called a duo-diode triode, or duplex diode triode.

Q. Since that time have there been any other variations of these multi-purpose tubes?

A. Yes, there have been many. For example, there was a variation of the 55 called the 85 which was similar except that it had a different filament voltage for the heater in the tube. Then there was a 75 tube introduced before very long, which also had a different heater voltage from the 55. Aside from such minor details these duo-diode triode tubes were generally similar.

Q. Is there any one type of tube which is used today

generally in radio receivers in using the diode system of automatic volume control?

A. You mean any one type exclusively?

Q. Yes.

A. No. There are many types.

Q. Do they have some diode tubes which are merely a diode with nothing else in the same bottle?

A. Yes. About 1935 the R. C. A. brought out the Type 6H6 tube, which was similar to the old Majestic tube in that it had in one envelope just a pair of diodes. This tube was otherwise quite different. It was one of the first series of metal tubes introduced about 1935. It had a metal envelope instead of a glass envelope.

Mr. Adams: I find that I failed to offer in evidence the Wheeler notebook No. 6. I should like to offer that in evidence, but to substitute for the pages, or rather to not put the actual book into evidence, but to use copies of the pages to which Mr. Wheeler has referred.

The Court: All right.

Mr. Adams: And, if upon examination of the notebook Mr. Darby desires to add any additional pages, we can include them also. And, I would like to offer that as Plaintiff's Exhibit 8.

(The notebook above referred to was thereupon marked Plaintiff's Exhibit No. 8.)

Mr. Adams: Also, with a similar understanding, I would offer page 75 from the Wheeler notebook 8 as Plaintiff's Exhibit 9.

(The page above referred to was thereupon marked Plaintiff's Exhibit No. 9.)

Mr. Adams: If you will excuse me for just a minute I would like to speak to my associate.

The Court: All right. We will take a short recess.

(A short recess was thereupon taken.)

Mr. Adams: That is all the direct examination of Mr. Wheeler, your Honor.

Cross Examination

By Mr. Darby:

Q. Mr. Wheeler, you heard Mr. Adams, in answer to the Court's question, state, as I understood it, that when you referred to your system you did not mean merely a diode used for automatic volume control purposes, but a diode with a particular circuit used for automatic volume control purposes; do you agree with that?

A. Yes.

Q. So that throughout your testimony where you referred to "my system" or "my diode system", you have intended to mean a system with a diode, with a particular circuit?

A. Yes.

Q. For automatic volume control, as distinguished from a diode with any type of automatic volume control, is that right?

A. Well, I do not know what the other arrangement would be, but I did mean a diode in a particular circuit arrangement.

Q. In a particular circuit arrangement. Have you referred to your system as including within that expression a diode with any circuit for automatic volume control purposes?

A. I am not sure I understand that. You see, my system is a diode, as I regard it, with a particular—

Q. (Interrupting): With a particular circuit?

A. (Continuing): —with a particular circuit arrangement, yes.

Q. As distinguished from a diode used for automatic volume control purposes with some circuit other than your particular circuit, is that right?

A. I think so.

Q. And you referred to the fact that at one time while commercial radio broadcast receivers were being manu-

factured with diode automatic volume control, there were also some receivers being manufactured with triode automatic volume control, is that right?

A. Yes.

Q. Now, about when was that?

A. At the beginning of 1929.

Q. And how long did that last?

A. Without regard to the relative number of diode and triode receivers, that lasted for several years. It is hard to say exactly when the last model of triode a.v.c. was introduced.

Q. Well, during that period of time can you give me the names of some of the manufacturers who were making triode automatic volume control sets in competition with diode sets?

A. Yes. In 1929 I remember the Stromberg-Carlson Company was making a triode a.v.c. receiver, and I think there was a Bosch receiver with triode a.v.c., about 1929. Then there was still a hang-over from the Radiola 64 of the R. C. A., known as the Radiola 67, made in 1929, with triode a.v.c.

Q. So that there was Bosch and Stromberg-Carlson at that time?

A. Yes.

Q. Were either of those companies at that time licensees of Hazeltine?

A. Stromberg-Carlson was.

Q. Now referring to the use of a broadcast receiver, let us assume, if you please, that it hasn't any a.v.c., just an ordinary broadcast receiver as we had in our homes prior to 1929 or 1928, or thereabouts. You explained to the court that in tuning into a station you wanted to have accurate tuning, because otherwise you would get distortion, is that right?

A. Yes.

Q. Now, how does distortion evidence itself on a listener?

A. Of course there are various kinds of distortion. Now, the kind that is introduced by mis-tuning the receiver depends a good deal on exactly how the receiver is designed. If the receiver is not very selective, then the receiver can be mistuned by quite a little and there won't be a great difference in the sound. A skilled listener can detect it easily, and it could be detected on high quality music.

Q. What I was interested in is just as a general proposition how distortion affects the listener, and I gather from what you say that it affects the listener because it in some way affects the sound, is that right?

A. Yes.

Q. And in what way does it affect the sound; does it make it mushy?

A. It makes it harsh, it makes the sound raspy, I think would be a fair description.

Q. So that going through the manual operation in the sets of those days, if you turned the controlling knob, or whatever it was, and you did not turn it to the proper tuning position, you would get a raspy or mushy or distorted sound out of the loudspeaker, is that right?

A. Yes, and the amount of distortion would depend on the characteristics of the particular set.

Q. Certainly, as well as the degree of mis-tuning?

A. Yes.

Q. And if you turned that knob from that position toward the true tuning position, that sound would clear up until you had the clear sound as you came into correct tuning position, is that right?

A. Yes.

Q. And as a matter of fact that is the way that all sets were tuned prior to the automatic volume control, wasn't it?

A. No, there was a combination of effects there. When you would de-tune it is true that this distortion was evidenced, but the major effect on de-tuning was that the signal became much less loud at the loudspeaker, so that what actually happened, as you tuned through resonance, first you would hear the signal weakly, and while distorted the distortion wouldn't be very noticeable because of its weakness. Then the signal would reach the loudest volume from the loudspeaker in a good undistorted condition. Then as you turned the dial still further the signal became much weaker, and at the same time distorted, but generally the distortion wasn't very objectionable because the signal would be so much weaker.

Q. Now, was that true with respect to all signals, or is that true with respect to the distant stations, as distinguished from the nearby stations?

A. All signals.

Q. All signals. Let me refresh your recollection as to the concerns who were manufacturing triode types of a.v.c. You gave me two of them, Stromberg-Carlson and Bosch. How about Amrad, the Amrad receiver?

A. I am not sure; I can look that up if you like.

Q. Will you do that, please, Mr. Wheeler?

A. Yes.

Q. How about Grigsby-Grunow?

A. They made the triode a.v.c about that time. I wasn't sure whether it was 1929 or 1930.

Q. And was the Grigsby-Grunow a licensee under the Hazeltine patents?

A. They became a licensee around that time. I am not sure of the exact year.

Q. Will you also look that up for me?

A. Yes.

Q. I am interested to know whether Grigsby-Grunow at any time while it was a licensee of Hazeltine manu-

factured a triode a.v.c. receiver in competition with diode a.v.c. receiver?

A. I think I can tell you that much. I think it did.

Q. You think it did?

A. Yes.

Q. How about Brunswick-Balke-Collender Company?

A. They had a triode a.v.c. system on the market, I am quite sure, and there again I would have to look up the date.

Q. Well, will you look that up?

A. Yes.

Q. They were licensees at some time of Hazeltine?

A. They became a licensee around that time also.

Q. So I am likewise interested in having you ascertain whether or not Brunswick-Balke was a licensee of Hazeltine at the time it was manufacturing and selling the triode a.v.c. receiver in competition with diode a.v.c. receivers?

A. Yes.

Q. Now, you have referred throughout your testimony to the diode as a detector?

A. Yes.

Q. And I notice in your patent that the diode is referred to as a rectifier. Is there any difference between a detector or rectifier, or are those terms used synonymously?

A. I think, for the purposes that we are talking about, the terms mean about the same thing.

Q. They mean about the same thing?

A. The difference in the terms is this; the detector refers, by word, to the process of detection. Now, a rectifier can also be used for other purposes, but it is equally useful for detection, and in the things we are talking about the terms mean about the same thing.

Q. Well, will you explain very briefly and non-technically, if you please, just what a rectifier is?

A. A rectifier is a device which takes an alternating current of any frequency whatever and obtains from that alternating current, either directly or indirectly, a rectified current which has a direct current component, let us call it. That is, it tends to respond to the pulses of this alternating current, or alternating voltage, in one direction, and produce, in the output circuit, a current with a uni-directional component instead of an alternating component.

Q. Well, would you agree with me that a rectifier takes the oscillating or alternating current and acts on it in some way and passes out a direct current?

A. That is a pretty good way of describing it.

Q. All right. And in your a.v.c. connection from the detector back to the grid or amplifier which you wish to control, that is a direct current connection, is it not?

A. Yes.

Q. So that that connection is from the output side of the detector; is that right?

A. Yes.

Q. But the current coming into the input side of the detector is an alternating or oscillating current?

A. Yes.

Q. Therefore, to get it, it is the action of that detector, the rectifying action of that detector which makes the direct current available for your automatic volume control?

A. Yes.

Q. And when a two-electrode device or a diode is used as a detector, it, of course, is operating as a rectifier; is that right?

A. Yes.

Q. But it is not operating as an amplifier ordinarily, is that correct.

A. I guess always it isn't.

Q. Always it is not operating as an amplifier?

A. Yes.

Q. When a three-electrode tube is operating as a detector it both rectifies and amplifies; is that correct?

A. Yes.

Q. So that is one distinction between a two-electrode detector and a three-electrode detector. You agree to that?

A. Yes.

Q. Now, I think we can very briefly synopsize your work leading up to your Washington receiver, so as to materially shorten the cross-examination. As I understand it from your testimony, the first record you have in your notebooks which records a realization on your part of the desirability of volume control is your record on page 14 of your notebook dated July 9th, 1925; is that correct?

A. You mean automatic volume control?

Q. Yes.

A. Yes.

Q. And from that time until some time during the Christmas holiday of that year, all the recordings in your notebook to which your attention was directed in your direct examination having to do with the subject of automatic volume control, consisted of theories or—your theories which you recorded, or proposed arrangements that you intended to try out; is that correct?

A. Yes.

Q. My understanding of the statement of counsel for the plaintiff, as well as of the claims of your patent, at least a feature of your invention consists of employing a diode with a connection from the ontput of that diode back to the grid of a preceding amplifier with the utilization or the provision of means for maintaining the anode of the diode negative with respect to the filament of the amplifier. Do you agree with that?

A. I don't think you intended to ask the question the way you did. It asks if I agree with what you heard.

Q. I will try it again. As I understand what you have referred to as your system, it employs, that is, your system as covered by the patent here in suit, the reissue patent, it covers and claims the use of a diode; is that correct so far? Is my understanding so far correct?

A. That is part of it.

Q. Yes.

A. Yes.

Q. That is correct. It also includes a connection between the anode of the diode back to the grid of a preceding amplifier; is that correct?

A. Yes.

Q. And that connection also includes an instrumentality, a resistance, which maintains the potential of the anode of the diode negative with respect to the filament of the vacuum tubes?

Mr. Davis: Of the amplifier.

Q. Of the amplifier.

A. That resistance is in the circuit. It isn't precisely in the direct current connection itself.

Q. I understand but it is in the circuit?

A. Yes.

Q. And it serves the function of maintaining the anode of the diode at a potential which is positive relative to the potential of the filament of the amplifier?

Mr. Davis: Negative.

Q. Which is negative relative to the filament of the amplifier; is that right?

A. Yes.

Q. Now, it is a fact, is it not, that the first record in your notebook of the use of a diode, or the proposed use of a diode is that of December 9th, 1925, found on page 83 of your notebook? No, I am sorry—

Mr. Davis: I think it is page 89.

Q. (By Mr. Darby): Strike that out and make it December 17th, 1925, on page 89 of your notebook.

A. Yes.

Q. That is the first record of a conception on your part of using the diode as distinguished from a triode?

A. Yes.

Q. Then none of the entries of your notebook prior to page 89 has anything to do with the invention of your patent here involved, do they?

A. I don't know what you mean by "anything to do." They led up to it.

Q. They don't disclose it?

A. That is correct.

Q. They do not disclose it. All right. On page 88, for example, that shows a triode detector rather than a diode detector; is that correct?

A. Yes.

Q. And, it is tube No. 5 which is the a.v.c. detector tube in that circuit, is that right?

A. Yes.

Q. And there is included in the direct current connection from the anode of that tube back to the grid of the preceding amplifier tube a battery, which is shown by the usual symbol of a battery with a plus and minus terminal sign; is that right?

A. Yes.

Q. And, in that circuit arrangement, how is the potential, what is the potential of the anode of the a.v.c. detector tube No. 5 relative to the filament of the amplifier tube?

A. Positive.

Q. It is positive?

A. Yes.

Q. The direct antithesis of what is an element of your invention as you agreed with me a minute ago, is that right, so far as potential is concerned?

A. Yes.

Q. Now, at the time that you were working on this problem, as I understand it, you were a student at Johns Hopkins, and working during the summer months with Hazeltine Corporation. Was the Hazeltine Corporation the only one that you had worked for during your student days in this field?

A. No, I had spent the summers of 1921 and 1922 at the Bureau of Standards.

Q. In the radio branch?

A. In the radio laboratory as a laboratory assistant.

Q. I see. How old were you then, in 1920 and 1921?

A. In 1921 I was 18.

Q. And, with reference to the first entry to which our attention was called on July 9th, 1925, page 14 of your notebook, did you at that time believe that you were the first working in this field to suggest automatic volume control to cure this problem that you had recognized, or to your knowledge was that a problem which was well known in the art, and others were working on it or had supplied solutions for it?

A. To my knowledge it was not well known, and I thought I was the first worker in the field.

Q. At that time you thought you were the first worker in the field?

A. Yes.

Q. Then, you did not know of anybody else doing any work along those lines?

A. That is correct.

Q. Did you take any steps to find out whether anybody else was working along those lines, or was its novelty to you accepted as sufficient for the belief that you were the pioneer of that?

A. I talked it over with quite a number of other engineers. Naturally I was always alert to any remarks

they might have made about work by any others in the field. And, it wasn't until quite a while later that I had the first suggestion from any of these other engineers that there might have been someone else working in the field.

Q. Then, your first knowledge of that was suggestions received from some of these other engineers that you had talked it over with?

A. Yes.

Q. And you say a long while after that. Could you give me an approximate idea?

A. I think early in 1926 was the first suggestion I had from anyone else, and then it was very hazy.

Q. It was very hazy as to what they were doing?

A. Yes.

Q. What the engineers knew they were doing?

A. Yes.

Q. Did you take any steps to find out what they were doing?

A. Only by inquiring. Naturally I couldn't go to the Telephone Company and ask them what they had done about a.v.c.

Q. Naturally. Let me ask you this, Mr. Wheeler, with reference to this meter that you proposed using in connection with your automatic volume control; was the use of a visible indicator for proper tuning in radio receiving equipment known to you at that time?

A. You mean around the end of 1925?

Q. Yes.

A. We had used it in the laboratory at the time.

Q. I mean as practical use, its public use, commercial use. Was that known to you at that time without a.v.c., a visible indicator for accurate tuning?

A. In commercial use?

Q. Yes.

A. I don't think so. I regarded it just as a laboratory test.

Q. Just as a laboratory test. So far as you know nobody prior to yourself either in practical use, or in publications, had ever used a visible indicator for indicating proper tuning resonance?

Mr. Davis: Do you mean know or knew?

A. Yes. In laboratory for very special experiments.

Q. The use of a visible indicator was known to you to be old at that time?

A. Yes.

Q. So that you do not claim to be the originator of the visible indicator, except when it is used in connection with a.v.c., is that right?

A. I think so, yes.

Q. Now, what the visible indicator does, what the meter does, is show to the eye as distinguished from the ear when perfect resonance or perfect tuning is effected, is that right?

A. Yes.

Q. And, a meter used for that purpose would function for that purpose regardless of whether or not an automatic volume control connection or circuit was used, wouldn't it?

A. Well, after a fashion. I had occasionally used a meter for tuning the receiver without automatic volume control. And, it was fairly good on some signals, but it didn't help very much as a rule. Weak signals produced such a very small indication on the meter, and strong signals tended to overload the detector, or else you had to adjust the amplification on each signal if you wanted to get a good meter reading.

Q. Now, the principle of the meter or the visible indicator is that, assuming it is a meter, it has a needle, has it not?

A. Yes, or some alternative.

Q. Or some alternative?

A. Something you can see moving.

Q. Let us assume it is a needle just for the moment.

A. All right.

Q. And the principle of it is due to the operation of the electrical instrumentalities, when that needle was in one position, or at one position on its scale, perfect resonance has been achieved; whereas, if it was on any other position on the scale it was out of resonance and it was out of resonance to a degree proportional to its displacement from its desired position; is that generally right?

A. I think that is the right idea. Really what happened is when you were tuned to resonance you caused the pointer to move as far as you could in one direction.

Q. All right. And, of course I understand that there are a number of extraneous circumstances, such as static and conditions of that nature, over which we have no control?

A. Yes.

Q. But let us assume perfect conditions, for the purpose of my question. A meter used for that purpose would get maximum condition regardless of whether or not there was an automatic volume control in the receiver or not, would it not?

A. Maybe I had better explain exactly the trouble we had before we—

Q. (Interrupting): Could you answer that question and then make any explanation you want?

A. I think the maximum position of the pointer would be a condition of resonance. But, the trouble—

Q. (Interrupting): That is in the situation that I have presented?

A. Yes.

Q. All right.

A. But the trouble we had was that if you were tuning in a weak signal you would have to turn up the amplification in order to get a good reading on the meter. Then if you tuned into a strong signal, the same amount of amplification, while it would read on the meter all right, would overload the detector, so that while the meter was useful perhaps for tuning the receiver to resonance, I did not regard it as a useful instrument for the practical listener.

Q. I understand.

A. (Continuing): To use to tune his receiver, that is all.

Q. I understand that. All I wanted to get you to agree, and I think that you have, was that a meter as a visible indicator of resonance would work for that purpose and nothing else?

A. Yes.

Q. Just as well without an automatic volume control connection as it would with it, just for that purpose alone?

A. Not just as well. There was a very great difference of degree. It became very easy to manipulate when we got the a.v.c.

Q. I understand you claim ease of manipulation, but my sole inquiry is that a meter would indicate resonance regardless of whether or not there was an automatic volume control circuit employed?

A. Yes.

Q. You agree to that?

A. Yes.

Q. And stated another way, the automatic volume control arrangement would automatically control the volume regardless of whether or not there was a meter in the system?

A. Yes.

Q. In other words, each of them would perform their own function independently of the other, though some advantage might arise by using them both together?

A. That is correct.

Q. Now, in your letter of December 15, 1925, Plaintiff's Exhibit 24-A, your letter to Mr. Dreyer, the last sentence of the letter, and I will show you this, the last sentence of the letter is as follows: "I think I can work it now with only one added tube." You meant by that, did you not, that you were of the belief on December 15, 1925, that you could obtain automatic volume control with only one tube in addition to the number of tubes that were required for any particular set, is that right?

A. Yes.

Q. And the reason why you underscored with double lines "only one added tube", was that your work up to that time, or shortly before that time, had led you to the belief that you needed more than one additional tube?

A. Yes.

Q. Is that right?

A. Yes.

Q. And that, as I think you explained to the court, due to the expense of the tubes they were the major items of expense in the receiver, was an important factor, in your opinion?

A. Yes.

Q. And will you turn to page 89 of your notebook again, please? The entry of December 17th, just two days later. In the middle of the page you show a wiring diagram in which you employ two detectors, is that right?

A. Yes.

Q. One of those detectors is for automatic volume control purposes, is that right?

A. Yes.

Q. And that is the added tube, or at least that is one arrangement that you had worked out on paper illustrating being able to obtain automatic volume control with but one added tube, is that right?

A. Yes.

Q. The only function of the second tube from the left in that circuit is for automatic volume control? It did not do any detecting of the signals for purposes of reproduction into a loudspeaker, is that correct?

A. That is correct, that is tube No. 5.

Q. Tube No. 5?

A. Yes.

Q. And the detector tube of the circuit for that purpose, that is of producing audible signals in the loudspeaker, was tube No. 6, is that right?

A. Yes.

Q. You also referred to the minutes of the August meeting of the I. R. M. members, two mimeographed sheets of which are in evidence as Exhibit 13. You won't need a copy of them for this purpose. You refer to them as licensees, that is the members of this I. R. M. engineers, Independent Radio Manufacturers, as licensees. Licensees of whom?

A. Of the Hazeltine Corporation.

Q. They were all licensees of the Hazeltine Corporation, Independent Radio Manufacturers, Incorporated?

A. I think so, yes, that is my understanding.

Mr. Adams: Do you want me to state on the record anything about that, Mr. Darby?

Mr. Darby: No, I merely wanted to bring out, which I understood was the fact, that it was Hazeltine licensees and not R. C. A. licensees.

Mr. Adams: Yes.

Q. (By Mr. Darby): I understood you to say, Mr. Wheeler, that around 1928 or 1929 the R. C. A. brought

out the Radiola No. 64, and in 1929 the Radiola 67; did I correctly hear you say that?

A. Yes.

Q. And then I understood you to say that in the following year the diode system of automatic volume control was adopted exclusively. Now, I was wondering whether you were referring only to R. C. A., or if you were referring to R. C. A. at all, especially in view of your testimony, later testimony, led me to believe that there was a period of time of several years there when triode a.v.c. was in the market in competition with diode a.v.c., and including triode a.v.c. receivers manufactured by Hazeltine licensees. Now, what is the fact?

A. I think the first statement you made was not in accord with what I said. At least, it does not sound right, and I do not think I said that.

Q. All right, you did not intend to say that anyhow?

A. Not exactly, no.

Q. All right. I am showing you a diagram of the Philco receiver which is in evidence as Plaintiff's Exhibit 18 and concerning which you were interrogated. Which is the detector in this arrangement? Which tube is the detector, tube or tubes?

A. In the upper row of symbols, of circles, the fourth one marked 227 is the detector.

Q. That is the a.v.c. detector?

A. Yes.

Q. And what is the next tube to the right, also marked 227?

A. That is the first audio-amplifier tube.

Q. That is not a detector, then?

A. No.

Q. Does the 227 in the Philco system operate for the dual purpose of a.v.c. rectification as well as signal detection?

A. Yes.

Q. It does. You referred to the reliability of Rider's manual as being accepted by the engineers in the art and by yourself as being correct, and this Model 95 Philco on page 1-23 of Rider's Manual, Volume 1, how is the tube 227, the fifth one, characterized in this manual?

A. At the bottom of the page is a table entitled "Voltages read with A. C. set tester." And that particular tube 227 is said to be in the circuit as a detector amplifier, abbreviated det. amp.

Mr. Darby: I ask to have this page of Rider's Manual marked for identification as Defendant's Exhibit C for identification. May I mark it myself, your Honor, temporarily for that purpose?

The Court: Yes.

(Page 1-23 of Rider's Manual was thereupon marked as Defendant's Exhibit C for identification.)

Q. Would you trace the a.v.c. circuit of the Philco receiver, the wiring diagram of which is shown on Plaintiff's Exhibit 18, starting with the output electrode of the triode connected as a diode, the first tube 227?

A. The part of the a.v.c. circuit which goes back to control the amplification—that is what I have sometimes called the direct current connection—starts from the fourth tube from the grid and plate connected together and goes to the right through the resistance labelled No. 25 and then down through the resistance labelled No. 26 and then to the left at the bottom of the diagram. Then, under the first and second tubes, this connection proceeds upward to the grids of these tubes in each case through a coil.

The connection to the second tube goes upward through the coil just to the right of No. 13. The connection to the grid of the first tube goes through the resistance No. 7 upward through coil No. 9 and then to the grid.

Q. I don't know whether I covered with you the question of whether or not Bosch was a licensee of Hazeltine. I don't think I did. Can you tell me whether or not Bosch was a licensee of Hazeltine during the time it was making and selling triode a.v.c. receivers?

A. About that time I know it was not. It has been for several years now.

Q. It has only been a licensee in the past several years?

A. I think so.

Q. Will you verify that for me?

A. Yes.

Q. I think you have testified that it is your belief that beginning at about 1929 a number of the manufacturers of radio broadcast receivers began using your diode system of automatic volume control, with the limitations we have agreed on to that statement. From that, am I to understand that all of the concerns that you referred to used a separate vacuum tube with just two electrodes in it as the diode detector, or was there use of a multi-purpose tube, multi-electrode tube, two of which electrodes were used for automatic volume control purposes?

A. This particular tube with diodes as well as the triode in the same envelope, is that the kind of multi-purpose or multi-electrode tube you refer to? Or, do you mean in general any tube with more than two electrodes?

Q. Any tube employing more than two electrodes, which would necessarily include all of these duplex diode—

A. (Interrupting): And even an ordinary triode or an ordinary tetrode.

Q. No. I quite agree with you, Mr. Wheeler, that an ordinary triode, two electrodes of which are tied together, is a diode. I am quite willing to agree with you on that.

A. Then, I am not quite clear whether the question

refers to a trick use of a tube having three or four electrodes. There were some such uses which amounted to a diode a.v.c.; or, whether you mean these tubes which had really a diode and something else in the same envelope.

Q. Maybe I can simplify it for you and ask you this; did any of the manufacturers of radio receivers adopt an ordinary two-electrode vacuum tube for automatic volume control as such?

A. In a few models they did.

Q. And they very quickly discontinued those, did they not?

A. I am not sure. There are one or two special purposes where they have used a type of tube which was ordinarily used as a power rectifier diode in the diode a.v.c.; but, those are unusual.

Q. And, therefore, the volume of use to which you referred as use of your diode system has been in connection with multi-purpose or multi-electrode tubes, is that right?

A. You mean after these tubes became available?

Q. Yes.

A. Yes.

Q. And, reference in your direct examination was made to the screen grid type of tube. When did they become available on the market, if you know?

A. It was available for several years before it was actually used. The time that I remember was about 1929 when it came into wide use.

Q. And do you know when the indirectly heated cathode type of tube came on the market? Was that about the same time?

A. Well, there again there was a little period of development, but it was around 1927 or 1928.

Q. So that the indirectly heated cathode was adopted

in the market prior to the adoption of the screen grid type of tube?

A. Yes.

Q. And, I notice that you understood, when Mr. Adams referred to a screen grid tube, just what was meant by it, and also when I asked you the question. Will you tell me just what a screen grid tube is, very briefly and simply for the purpose of the record?

A. Yes. A screen grid tube is a special type of amplifier tube that has in it all the elements of a triode, or a three-electrode tube which perform their normal functions the same as they do in a triode amplifier. It has, in addition, a fourth element, and that fourth element is an electrode much like a grid interposed between the grid and the plate or anode.

Now, we call this the fourth electrode chronologically, but in the tube the order of electrodes is cathode, grid, screen, and then the plate or anode.

Now, the purpose of interposing this screen grid in the tube was to prevent a feed back in the tube which would cause oscillations or whistles in the operation of the set.

Q. When you say feed back, to prevent that, you mean inter action of the circuits which are connected to those electrodes so as to set up oscillations or disturbing influences?

A. Yes, to prevent inter action between the grid and plate circuits connected to the tube.

Mr. Darby: That is all. Thank you.

HAROLD A. WHEELER, was thereupon recalled as a witness herein, and having been previously duly sworn, testified further as follows:

Re-Direct Examination

By Mr. Adams:

Q. In the cross-examination yesterday Mr. Darby asked you what you meant by your system of automatic volume control, and I find it is recorded on page 147 that he said:

> "Q. So that throughout your testimony where you referred to 'my system' or 'my diode system', you have intended to mean a system with a diode, with a particular circuit?
>
> "A. Yes."

Mr. Darby said:

> "Q. For automatic volume control, as distinguished from a diode with any type of automatic volume control, is that right?
>
> "A. Well, I do not know what the other arrangement would be, but I did mean a diode in a particular circuit arrangement."

Now, what I would like to ask you is this; do you know of any sets using a diode system of automatic volume control today which do not use your particular circuit arrangement for securing diode automatic volume control?

A. No, I do not.

Q. Now, also, Mr. Darby asked you to explain something about the action of a rectifier, and I find at page 152 a discussion of that subject, and you say concerning the rectifier:

"That is, it tends to respond to the pulses of this alternating voltage, in one direction, and produce, in the output circuit, a current with a unidirectional component instead of an alternating component."

Now, what I would like to ask you is whether in your system of automatic volume control you use the direct current component or the direct voltage, which is produced by the rectifier in order to control the preceding amplifier?

A. I use the direct component of voltage or potential.

Q. You mean by voltage or potential, you mean those two words describe the same thing?

A. Yes.

Q. And you convey that potential from the rectifier back to the grids of the controlled tubes over a connection which you call a direct current connection; is that right?

A. Yes.

Q. Why is it called a direct current connection?

A. That describes generally a connection which is capable of transferring the direct component of either current or voltage. It happens that we have more commonly referred to direct currents than direct voltages, but a direct current connection is a connection that is capable of transferring either direct current or direct voltage, and in this case it does transfer this direct component of voltage.

Q. Also Mr. Darby asked you to clarify for him a statement concerning the operations of the Radio Corporation of America, and I am afraid, just from reading the record, that it is left somewhat confused. Mr. Darby is reported—

The Court: What page?

Mr. Adams: 163.

Q. (Continuing): —as saying:

"Q. And then I understood you to say that in the following year the diode system of automatic volume control was adopted exclusively. Now, I was wondering whether you were referring only to R. C. A., or if you were referring to R. C. A. at all, especially in view of your testimony, later testimony, led me to believe that there was a period of time of several years there when triode a.v.c. was in the market in competition with diode a.v.c., and including triode a.v.c. receivers manufactured by Hazeltine licensees. Now, what is the fact?

"A. I think the first statement you made was not in accord with what I said. At least, it does not sound right, and I do not think I said that."

Now, will you just briefly tell me what the fact is about the R. C. A. operations?

A. In 1928 the R. C. A. brought out their first receiver with automatic volume control of the triode type. This receiver was carried over in 1929. In 1930 the R. C. A. brought out no receivers with automatic volume control of any kind. In 1931 they again brought out receivers having the triode form of a.v.c. In 1932 they brought out their first receivers with the diode form of a.v.c.

After 1932 their use of my diode a.v.c. arrangement increased rapidly, and their use of the triode a.v.c. arrangement decreased rapidly. Within a couple of years after that their use of the triode form of a.v.c. had vanished or at least was limited to models left over from the previous years.

Q. Now, at page 164 Mr. Darby called to your attention a circuit diagram in Rider's Manual, which was a circuit of the Philco Model 95, and which was marked Defendant's Exhibit C for identification. This circuit dia-

gram also contains some additional information in words and symbols. I would like to ask you first whether that circuit diagram is a correct circuit of the Philco Model 95 (handing document to witness)?

A. It is.

Q. Is it the same as the circuit which you have previously identified as Plaintiff's Exhibit 18 (handing document to witness)?

A. Yes, it is.

Q. Do you know whether the information on that diagram in Rider's Manual is a correct statement of the information from the Philco Company's service manual?

A. It is.

Q. Mr. Darby called to your attention the label "det. amp." which was included in the tabulation as applying to the second tube numbered 227, and you stated that that stood for "detector amplifier." Do you know why that was called "detector amplifier?"

A. After this receiver was designed and the Philco men were preparing their service bulletins, they pointed out that—

Q. (Interposing): To whom? Pointed out to whom?

A. They pointed out to me that if we called this particular tube the first stage of the audio-amplifier that would necessitate a revision of the notions then prevalent about how the first and second stages should work, because the stages which had previously been the first and second stages would now be the second and third stages.

Q. Of audio-amplification?

A. Yes. So, I suggested that that stage might be called the detector amplifier, meaning that it was the amplifier which was associated directly with the diode detector.

Q. Also, on page 164 Mr. Darby asked you to trace the a.v.c. circuit of the Philco receiver by reference to Plaintiff's Exhibit 18. Will you tell us in addition to what

you have already stated in answer to Mr. Darby's queston, where the filter is in that automatic volume control connection?

A. Yes. There are two filters. The first filter, the one which removes the carrier frequency component from the output of the detector, involves the resistance 25 which I mentioned in the direct current connection and the shunt condenser 27. Those elements take out the carrier component of the detector output. But, those elements leave in the connection the modulation frequency component. The modulation or audio component is taken out by the filter including the resistance 26, and then over on the left the condensers 6 and 12 associated with the first two tubes in the receiver.

The resistance 7 has only a slight influence on that filtering action, so we can regard the resistance 26 and the condensers 6 and 12 as comprising the time constant filter for taking out the modulation fluctuation from the direct current potential fed back for controlling the amplifier.

Q. On page 166 I think there is an answer needed. The question is:

> "Q. And, therefore, the volume of use to which you referred to as use of your diode system has been in connection with multi-purpose or multielectrode tubes, is that right?
>
> "A. You mean after these tubes became available?"

Mr. Darby says:

> "Q. Yes."

And then goes on with another subject, namely the screen grid type of tube.

Now, what I would like to ask you is what is the

answer to Mr. Darby's question which I have just read to you?

A. With the interpretation which I secured by my query, the answer is "Yes."

Mr. Adams: That is all.

Re-Cross Examination

By Mr. Darby:

Q. Have you handy, Mr. Wheeler, a copy of that Philco circuit?

Mr. Davis: Exhibit 18?

Mr. Darby: Yes.

Q. (By Mr. Darby): With reference to the amplifier detector tube, the second from the right-hand end, that is it was called by that name on the Philco Rider's Manual, the detector amplifier, rather, in the Philco manual, what is the grid voltage on that tube, do you know?

A. The grid voltage on that tube is the rectified voltage attained from the diode directly and it comprises both the direct current component of the voltage and the modulation component, but the carrier component is filtered out before it reaches that grid.

Q. And what was it in value, if you know?

A. The amount of voltage on that grid?

Q. Yes.

A. Of the order of five volts in normal operation.

Q. And what was the plate voltage on that tube?

A. It is not marked on this Exhibit 18, but I think it is given in that Rider's Manual.

Q. Just state what it is (handing manual to witness).

A. The plate voltage on that tube varies during operation. On this table in Rider's Manual it is given as 27 volts, which I think was the value in the absence

of any signal. Now, when the signal was received the direct current component of the voltage on that grid affected directly the plate voltage also, so the plate voltage would increase as the voltage on the grid increased.

Q. So the 27 volts was the non-operating voltage on that plate?

A. The voltage in the absence of a signal.

Q. Yes. Now, Mr. Adams asked you in re-direct examination if you know of any diode automatic volume control circuit in use today which was not the diode and circuit of your invention, and I understood you to say you knew of none. It sounded to me as though that question was limited to today's use. Do you know of any diode automatic volume control and circuit at any time which was not of your invention, not included within your invention?

A. In use or just described?

Q. In use or described? Let's canvass both situations.

A. Yes. I wouldn't be sure about trick circuits that have been described now and then, because one cannot keep track of all of those publications.

Q. Do you know of any?

A. I have paid more attention to the things which had real commercial significance.

Q. Will you answer my question, please?

A. I am not sure whether I have seen them or not. I don't have any in mind at the moment.

Q. All right. Then at the moment you don't know of any diode automatic volume control other than that which you invented and as covered by your patent here in suit?

A. You mean having a diode anywhere in the control circuit?

Q. Using a diode with a particular circuit or some circuit to effect automatic volume control?

A. There are so many ways a diode can be used in the circuit and has been proposed from time to time, which I don't really regard as a diode automatic volume control, because the diode is not used directly, that is, not as the important element in the control system. Now—

Q. (Interrupting): Are you through?

A. My only difficulty is that I have in the back of my mind more or less indefinitely such a large number of arrangements that have been proposed in recent years, and while I don't—

Q. Have you finished?

A. I don't have any particular ones in mind, but I think I could find some which have a trick arrangement with the diode, that have been shown.

Q. Do you know of any diode automatic volume control that has been used in the radio broadcast receivers which are not of your invention or included within your invention, at any time?

A. I think not.

Q. You know of none. You see, my difficulty, Mr. Wheeler, is this: I want to know what your position is in order to be able to meet it. Then, am I correct in understanding that it is your claim that the use of the diode for automatic volume control is your invention?

A. I think that is what I was just explaining. There are some trick circuits that have a diode in them.

Q. That you know of?

A. Yes. At least I know I could find some because I have more or less an indefinite recollection of seeing them.

Q. Which you say does not incorporate your invention?

A. Yes.

Q. Then you do not claim broadly to be the inventor

of the use of a diode for automatic volume control; is that correct?

A. That is.

Q. What you claim to be is the inventor of the use of a diode for automatic volume control in a particular manner or with a particular circuit?

A. Yes.

Q. Now, just what is that particular circuit, so that I will have a measure?

A. Yes. It is the arrangement in which the received modulated carrier signal is amplified to a high voltage and applied to a rectifier for obtaining the rectified voltage directly. Now, this rectifier circuit in the system that I call my diode arrangement is the combination of the diode and a high resistance so that a rectified voltage is obtained which is nearly as great as the applied signal voltage and in which the high resistance makes the operation relatively independent of the individual characteristics of the diode. Then this rectified voltage has its fluctuation components, the carrier component and the modulation component, removed by filtering and is conducted back to the grids of the amplifier for controlling the amount of amplification.

Q. And that is your understanding of the measure of the invention you claim in your patent?

A. Yes.

Q. And that you would have no just cause to claim infringement by an apparatus which did not operate in that way or be composed of those instrumentalities?

Mr. Davis: Well, your Honor, I object to that. After all, the plaintiff owns the patent, and if it is infringed, it is the plaintiff's cause.

Mr. Darby: I withdraw the question, Mr. Davis. I withdraw the question and put it this way:

Q. (By Mr. Darby): And no apparatus that did not

have those instrumentalities functioning in that way would, in your opinion, be embodying your invention; is that right?

A. I think so.

Q. Thank you. Now, I asked you yesterday to ascertain whether or not a certain number of companies were making and selling radio broadcast receivers employing triode a.v.c. in competition with diode a.v.c., and you were going to find out for me?

A. Yes.

Q. Have you done so?

A. I am looking up that information, but I had to communicate with my office and I will try to have it tomorrow morning.

Q. Yes. You will be here to give us that information?

A. Yes.

Q. And give it through Mr. Davis. And am I correct in understanding that the triode a.v.c. was the first a.v.c. that was incorporated in radio broadcast receivers?

A. Except for the few receivers made by the Howard Radio Company.

Q. Yes. Those receivers, approximately six in number, that sold for about $6,000 or $3,000 each?

A. Something like that.

Q. How many tubes were there in those receivers, do you remember?

A. There were nine tubes in the main part of the receiver, and two or three additional tubes in the power units.

Q. But the first large quantity production of automatic volume control receivers were of the triode a.v.c. type?

A. Yes.

Q. That is right?

A. Yes.

Q. And many, or at least some of the manufacturers

of those receivers were at the time Hazeltine licensees, were they not?

A. You mean at first?

Q. Yes.

A. There were not very many at first.

Q. When a.v.c. was first brought out on the market some of those at least that brought them out on the market were Hazeltine licensees?

A. Yes.

Q. Is that right?

A. Yes.

Q. And when they were Hazeltine licensees they were also licensees under your patents?

A. Yes.

Q. And they did not have to pay any additional royalties, did they, to use the invention of your patents rather than the triode a.v.c.?

A. No.

Q. In other words, this royalty arrangement was they paid a flat percentage or flat amount for license under all of your patents?

A. Yes. I don't know about the flat amount, but at least they paid the same amount for any number of the patents.

Q. Regardless of whether they used one or more?

A. Yes.

Q. Of the patents?

A. Yes.

Q. And if they were making one instrumentality, which came under some patents they could have said it came under other patents without altering their royalty requirements, is that right?

A. Yes.

Mr. Darby: That is all.

Mr. Adams: That is all.

(The witness was thereupon excused.)

Mr. Adams: Has your Honor any questions? I was going to go on to the next phase of the case, your Honor.

The Court: All right.

Mr. Adams: There is certain testimony which was given in the case against the Radio Corporation of America in Wilmington, and which Mr. Darby has stipulated may be given in this case, and I would like to offer at least certain parts of that at this time, and I don't know exactly in what form your Honor likes to have that appear.

I have prepared copies of it in binders with the exhibits which the witnesses referred to, and would offer them in evidence, using appropriate exhibit numbers, and then state, not as a part of the record, but just for your Honor's information, what the testimony relates to if that is all right.

The Court: I think that will be all right for my purposes. I don't know whether you would want this transcript re-read into the transcript of this case or not, or whether you would just use it as an exhibit for your record.

Mr. Darby: I think it is satisfactory to use it as an exhibit for the record.

Mr. Adams: I think so.

The Court: That would take care of that, then.

Mr. Adams: Well, let me explain for a moment, your Honor, some of these depositions are purely corroborative of Wheeler's notebook. Different people signed his notebook. It is just, perhaps, formality. Other people testified about the building of the Stromberg-Carlson receiver. Others testified about the demonstration of the Washington receiver. Those are, undoubtedly, all pertinent at this particular time; they come in appropriately right now. There is another group of witnesses who are the practical engineers with the Radio manufacturing

companies who testified as to their difficulties with the triode form of automatic volume control, and explained why they abandoned that, and went to the diode form of automatic volume control. Now, I don't know whether you want to have those put in at this time or not, but we can do so.

There are others, for example, there is the testimony of Mr. Friis who was, in the Radio Corporation case, put on the stand by the defendant. He was the Telephone Company engineer who testified as to what he did, and was there advanced in support of the defense of non-invention or anticipation. Also, there was another engineer from the Telephone Company named Betts, and his testimony was put in in support of the same thing.

Now, that stipulation says that either party may offer it. It may come more appropriate as a part of Mr. Darby's case; I don't know.

Mr. Darby: What I am really trying to do is simplify procedure, Mr. Adams. Can we agree that everything is going in so that when we go over our findings that we submit to the Court we can do it all at one time?

Mr. Adams: Sure.

Mr. Darby: All right.

The Court: I think we all understand one another. But, on page 8 of the plaintiff's proposed findings, Finding No. 17, down near the bottom of the page, the last sentence reads: "The testimony of these three witnesses has been stipulated and corroborates Wheeler as to the fact of the demonstration." Now, I see no reason why we should take a lot of time reading that testimony. You can just put a notation on the side there of the page in it, and if the question comes up later we can go into it. That is a simple illustration of what I have in mind.

Mr. Adams: Surely, I understand.

Mr. Davis: May I make just this one further suggestion about it, your Honor? All this matter of what testimony shall be put in by stipulation and when it shall be put in, be left in abeyance so that there will be no question of whether it is put in the prima facie case or rebuttal case.

The Court: All right.

PROFESSOR LOUIS A. HAZELTINE, was thereupon called as a witness on behalf of the Plaintiff herein, and having been first duly sworn, testified as follows:

Mr. Davis: If the Court please, I offer in evidence on the subject of the defendant's accused sets a booklet of the super-heterodyne radio receiver, factory series 175, which is one of the two sets that have been selected by the plaintiff as those upon which proof will be made. I offer that in evidence as Plaintiff's Exhibit—

Mr. Adams: 2-A.

Mr. Davis: 2-A.

Mr. Adams: The reason why I suggest 2-A is that we will have the physical receiver and we might offer that as Exhibit 2.

(The booklet above referred to was thereupon marked Plaintiff's Exhibit 2-A.)

Mr. Davis: At the same time I offer in evidence the Plaintiff's receiver, 175 type, as Plaintiff's Exhibit 2.

(The receiver above referred to was thereupon marked Plaintiff's Exhibit No. 2.)

Mr. Davis: I offer in evidence as Plaintiff's Exhibit 3, the plaintiff's set of the type of 178.

(The receiver above referred to was thereupon marked Plaintiff's Exhibit No. 3.)

Mr. Davis: And, I offer in evidence as Plaintiff's Ex-

hibit 3-A a card which shows the circuit diagram of the set number 178.

(The card above referred to was thereupon marked Plaintiff's Exhibit No. 3-A.)

Mr. Davis: I offer in evidence as Plaintiff's Exhibit 2-B a certain diagram of the Detrola Model 175, which circuit diagram is taken from the pamphlet Exhibit 2-A, but on which certain lines have been emphasized because it is Plaintiff's intention in the testimony of Professor Hazeltine to direct particular attention to those lines which represent the automatic volume control circuit.

(The diagram above referred to was thereupon marked Plaintiff's Exhibit No. 2-B.)

Mr. Davis: I offer in evidence as Plaintiff's Exhibit 3-B a similar circuit diagram of the Detrola Model 178 with lines emphasized, but otherwise a copy of the diagram on Exhibit 3-A.

(The diagram above referred to was thereupon marked Plaintiff's Exhibit No. 3-B.)

Direct Examination

By Mr. Davis:

Q. Professor Hazeltine, will you please state for us what your occupation and training is?

A. I am at present Professor of Physical Mathematics at Stevens Institute of Technology in Hoboken, New Jersey.

I graduated from Stevens in 1906 and spent the following year obtaining practical electrical experience in the works of the General Electric Company at Schenectady, New York. I then joined the Electrical Engineering Department at Stevens and rose through the various grades to become the full professor and head of the department of electrical engineering, which position I held for seven years.

In graduating from Stevens, I received the degree of Mechanical Engineer and subsequently I received the honorary degree of Doctor of Science from Stevens and the degree of Master of Arts in mathematics from Columbia University.

In 1915 I was attracted by the work of Mr. E. H. Armstrong, later Major and now Professor Armstrong, with his epoch-making circuits making the three-electrode vacuum tube an oscillator. I made an extensive study of such circuits, both mathematically and experimentally, during the next two years, and presented before the Institute of Radio Engineers in 1917 the first general mathematical treatment of that subject to be published anywhere.

During the World War I served as a consulting engineer in connection with radio receiver development in the Navy Yard at Washington. During that time I designed a receiver based on my own mathematical formulas which superseded receivers of similar range and went into extended use for a number of years thereafter.

I subsequently continued work in radio, serving as consultant, and I was the inventor of the Neutrodyne radio receiver which was the dominant broadcast receiver until the advent of the screen grid tube.

I was a member of three of the four national radio conferences called by the then Secretary of Commerce Herbert Hoover to make recommendations to the Department of Commerce for the purpose of regulating radio broadcasting in its earlier years.

I have served the Institute of Radio Engineers in various capacities, as chairman of some committees, as director, which I now am, and as president. I hold the highest grade of membership, that of Fellow, in the Institute of Radio Engineers, in the American Institute of Electrical Engineers, in the American Physical Society,

and in the American Association for the Advancement of Science.

Q. Have you examined the Detrola Model 175 receiving set that has been marked in evidence as Exhibit 2?

A. Yes, I have.

Q. And have you examined the wiring diagram which has been marked Exhibit 2-A and also the Exhibit 2-B which is the same wiring diagram with certain parts emphasized in blacker lines?

A. Yes, I have.

Q. Can you say whether or not this Detrola Model 175, Exhibit 2, is a broadcast radio receiver?

A. Yes.

Q. And does it contain automatic volume control?

A. It does.

Q. Now, referring to the diagram Exhibit 2-B, will you please give us a general description of the broadcast radio receiver and then proceed to point out for us the arrangements contained in it for automatic volume control?

A. The signal is received on an antenna which is represented by a triangle at the upper left-hand corner of the figure. In order that the listener may be able to receive signals over a wide range of frequencies, or wave lengths, there are provided three distinct input circuits represented by the row of coils, one above the other, at the left of the figure; and connected to each of those coils in the output circuit is shown a variable condenser which is adjusted in the factory to give the coils the proper relative natural frequencies when the main tuning condenser, which is shown close to the vacuum tube 6A7, is varied by the user. That constitutes the input circuit, and any one of the three coils may be selected by the operator by operating a switch which is indicated by a heavy arrow and three points to which it may connect, between the antenna and the first tube 6A7.

Q. Let me interrupt you a moment. What is the significance of the legends down at the left-hand corner of the diagram and the lines adjacent to the legends "broadcast", "foreign" and "police"?

A. They represent the three positions of the switch to which I have been referring. The left-hand position is one which connects to the lowest coil and gives the standard broadcast band, from 540 kilocycles to about 1700 kilocycles. Then the middle connection, which is the connection at which the switch is actually drawn, gives the so-called "police band", which is a somewhat higher frequency, and then the right-hand switch contact marked "foreign" gives a still higher frequency arrangement. That is used to pick up the so-called "short-wave" stations, many of which are foreign.

Q. Now, will you proceed with your description of the system?

A. Yes. For convenience, the emphasized lines are those representing connection to the foreign band merely because this made the lines shorter and easier to follow; and one has to then imagine the switch represented by the emphasized arrow to be turned to be in contact with the right-hand heavy line and not in its mid-position as shown.

The tube 6A7 is one kind of combination tube which serves the functions first of producing a local oscillation, which is done by the use of the coil and condenser arrangement down below this tube; then the tube mixes the local oscillation with the incoming signal, thereby introducing a modulation of the incoming signal, that modulation being at a frequency which is the difference between the frequency of the local oscillation and the frequency of the incoming signal. That is, broadly, the heterodyne system, but, as applied here, further, it is called the superheterodyne, which includes amplification in that newly

generated frequency, known technically as the intermediate frequency.

In combining the local oscillation with the incoming signal, the tube has the further function of amplifying the signal so that that signal given out from the output circuit to the right of the 6A7 tube is of greater amplitude than the signal coming in and impressed on its grid. In this output circuit, made up of a transformer—

Q. May I interrupt, Professor, before you pass on beyond that tube, I would like to ask you this; the tube 6A7, then, performs the function of the oscillator, and also the function of an amplifier?

A. Yes, sir.

Q. And it is enabled to do that because of this multiplicity of grids?

A. Yes, that is correct.

Q. And it has shown four grids there and one anode and one cathode, is that right?

A. That is the way it is represented. The one grid symbol is not actually in the form of a grid, nor does it function as a grid, but it is represented in that way because if it were drawn as usual with a straight line for an anode it would appear to be an obtruction. Actually it consists of two metal posts, one at each side of the stream. So, there are really, then, two anodes, the cathode, and three electrodes that have the form of grids—one of those, however, being a screen.

Q. And all those are included within one glass envelope with a single tube?

A. Yes.

Q. And those tubes are referred to as multi-duty tubes?

A. I believe so.

Q. Now, will you proceed with your tracing of the circuit?

A. The outpnt, which is here, the plate of the 6A7,

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that being the uppermost electrode in the diagram, is connected to a coil and condenser constituting a tuned primary circuit. That coil is coupled to a second coil which is also tuned by a condenser, giving a tuned secondary circuit, and that tuned secondary circuit is connected to a grid of the next tube, which is in the upper middle of the diagram and marked 6D6. That tube is an amplifying tube for the intermediate frequency, the transformer circuits to which I just referred being tuned to that intermediate frequency. The output of the 6D6—

Q. (Interposing): Before you leave that, may I interrupt again? Before you leave that I notice it also has additional electrodes. Will you just state generally what they are for?

A. This tube is of the screen grid type as is the 6A7. The control electrode, the thing that we ordinarily refer to simply as the grid in many cases, is the lowest zig-zag. Above that is the so-called "screen", which is the characteristic of the screen grid type of tube, and still above that third grid is a grid which is called the "suppressor". This is a somewhat special thing, and some tubes of the screen grid type do not have it. Then above that is the anode or plate which forms the output electrode in this tube.

Q. Will you proceed with your description?

A. That plate goes to a tuned transformer similar to the one in the input circuit to which I have previously referred. There is a primary coil connected directly to the plate across which is an adjustable condenser adjusted once for all in the factory. Coupled to the primary coil is a secondary coil also connected to a condenser adjusted in the factory. This secondary coil connects to the diode detector, which is the lower portion of the tube marked 75.

The Court: Just a minute there, professor; does that secondary coil have a reference number?

A. No, it is not marked here.

The Court: I am not so sure I am following him there, Mr. Davis.

The Witness: It is the coil that is emphasized.

The Court: All right, I see. I have it. All right, I guess this is a good time to stop for a while, anyway. We will take a recess.

(A recess was thereupon taken.)

Mr. Davis: Before I go on, if your Honor please, I should like to call attention to the fact that on this wiring diagram which has been put in evidence as Exhibit 2-B we have identified reference letters surrounded by circles. Indeed, while your Honor was out of the room, we added the reference letters 7 and 31 and incorporated those in the copies that you have.

Those reference letters have been taken from the Figure 1 of the Wheeler patent, that wiring diagram, and we have applied here the same reference letters to corresponding parts.

The Court: All right.

Q. (By Mr. Davis): Professor Hazeltine, will you proceed with your description of the wiring of this set?

A. I had reached the detector tube, which is the tube 75 tube as marked originally, and which is also marked with a 33 in the circle. That tube is a tube serving several functions but in a different way from that done in the 6A7. In the 6A7 those same functions were performed simultaneously by essentially the same parts of the tube, but in this 75 tube there are really three tubes in the same envelope which work quite independently; and of those three tubes one is the rectifier that we are particularly concerned with, and that is constituted by the upper vertical line marked 35-12 and by the slanting line adjacent to it marked 38. The upper vertical line is an anode and the slanting line is a cathode.

Then there is another anode just below the one that I have referred to, another short vertical line that we are not really concerned with. That is something which, together with a portion of the cathode 38, is used only when the set is not receiving signals. It is used to prevent the loudspeaker from giving out a noise due to the rotation of the motor which tunes the set. The motor and its connections are shown at the lower middle of the diagram, and one lead can be seen going from that motor circuit up, without any further connections except one, on its way to this lower anode. That, then, I need not refer to further as it has nothing to do with the normal operation of the receiving set. But, there is now in this tube a triode section. The cathode 38 actually is two cathodes, connected electrically but physically separate from one another. And, the one portion of that cathode, the grid directly above it, and the plate at the top, constitute an ordinary triode which serves as an audio-frequency amplifier. So that in the normal operation of the set there is rectification between the anode 35-12 and its section of the cathode 38. That rectification produces a modulated direct current, and that modulated direct current is passed through a resistance mostly in the part marked 51.—

The Court: Wait a minute, I didn't get that. Do you know where that is?

Mr. Davis: Down at the bottom.

The Witness: I will trace that out. Starting at 35-12 we have an emphasized connection going first to the left and then down through the coil, which I think is now marked 31, then to a heavy dot, and then down again through a resistance 34 to another heavy dot marked 52, and then down through the resistance 51 to a symbol which represents a so-called ground connection which means a connection to the metal frame or chassis of the

receiver. And, from the ground connection we go back to the cathode 38, because the cathode 38 is also shown as connected to a ground. So, all those connections marked with an inverted pyramid of horizontal lines which is a symbol for a ground connection, and all such connections are electrically one.

The rectified current, in taking that path, builds up a potential at the point 52 which has a direct component (that is, a direct current component) used for automatic volume control which, for the moment, I will not refer to in detail, and also has a modulation component, and that modulation component is passed to the audio-frequency grid of tube 75—that is, to the only grid which is present which is in the audio-frequency section, —and that is done through a condenser shown connected to an arrow-head. It is marked C-21 in rather faint lines in the original manufacturer's bulletin. That condenser then passes the audio-frequency pulsations up to the grid of the 75 tube, and the audio-frequency portion of that tube—

The Court: Wait a minute. Perhaps, Mr. Adams, you can stand up here and watch me.

A. (Continuing): The upper portion then of the 75 tube amplifies that audio-frequency potential, or that modulation potential, and passes it to the power tubes which are the two tubes one above the other marked 42, near the right of the diagram. On its way to one of those tubes there is another tube marked 76 which is used for phase reversal, a rather special use of a tube. Then the two tubes marked 42 form what is called a push-pull arrangement supplying the power to the loudspeaker. The loudspeaker is represented diagrammatically by the triangle and connections above it at the extreme right of the diagram.

Q. Let me interrupt you a minute there, Professor.

You spoke of this condenser passing the modulations or variations on to some place. Is it true to say that a condenser will not pass a direct current?

A. Yes.

Q. But will pass only a varying current?

A. That is correct.

The Court: Wait a minute. What is a varying current?

A. Well, strictly, an alternating current. That is, the condenser will pass a current which flows as much in one direction as in the other, but it will not pass any current which is predominantly in one direction.

Q. (By Mr. Davis): Will you explain that a little, how a condenser's plates are charged and how it passes the energy?

A. The alternating current—

The Court (Interrupting): The new term that was new to me was the varying current. Does the varying current and alternating current mean the same thing?

A. It would be better to say "alternating current" there.

The Court: I see.

Mr. Davis: I only used the word "varying" to include the pulsating current, but, after all, it is true to say, as I understand, the alternating current, because the pulsations are the alternating part of the pulsating current.

The Court: All right.

A. If we have any current that is varying continuously, we can separate it into two parts, one part which would be steady and only in one direction, and that would be the direct part, direct current part, and then the other part would be the part whose average value was zero; and it is that latter part that will be passed through the condenser and not the former, so that the pulsating

current can be resolved into a direct current and an alternating current, and the condenser keeps out the direct current but passes the alternating current.

Q. Now, will you proceed?

A. I think that I finished with the general operation of the receiver but did not go into the automatic volume control feature.

Turning again to the diode rectifier 33, there is, as I have already explained, an output potential developed by the current flowing negatively through the tube and out of the anode 12-35. That anode may, therefore, properly be called an output electrode, and that output potential includes—or that output current builds up a potential mainly at resistance 51 which is separated in the way that I just described generally. That is, the alternating part of that potential is used to pass on the signal to the loudspeaker after amplification, but the direct current part of that potential, which exists at the point marked 52, is led through the resistance 53 over the accentuated horizontal lines to the grid circuit of tube 9, which is the 6A7 tube toward the left of the diagram. It is also led to the grid circuit of the 6D6 tube which is at the middle of the diagram, but that connection, for simplicity, has not been emphasized, and I can, I think, confine my remarks to the 6A7 tube where the line is drawn heavily, so this direct current connection goes through resistance 53, passing towards the left, then it goes up a short distance and again horizontally to the left. It goes through the coil which, I believe, has been marked 7. Thence through the switch which we supposed closed toward the right-hand contact, and thence on to the grid 11 of the tube 9.

Q. Let me interrupt you, Professor. In the diagram here there is an emphasized line that crosses the horizontal line 36 and it is connected to the cathode 27 of

the tube 9. Is there a connection at that crossing of those two lines or not?

A. No. There is not a connection. The connection would be represented by drawing in a dot. So that there is no electrical connection at that point.

Q. So that this potential that you have been speaking of is not led through any connection there to the cathode 27?

A. No, sir. It is led only to the grid 11.

Q. Will you proceed?

A. Now that potential that we have referred to as being built up at the point 52, and as being led through to the grid 11 has at the point 52 still the audio-frequency modulation components and they have to be filtered out so that they will not be impressed on the grid 11. That is done by the filter consisting of the resistance 53, which is toward the right-hand end of this connection, and by condenser 54, which is near the left-hand end at the bottom—the left-hand portion of the diagram near the middle. What small pulsations of current get through the resistance 53 are easily passed by the condenser 54 to ground, which is also connected to the cathode 27, because that is grounded through a small resistance. And, those fluctuations or pulsations in potential, are, therefore, filtered away from the grid 11. The grid 11, therefore, receives only a direct current potential which is in a negative direction as desired for control purposes, and that potential is negative relative, not only to the cathode of the rectifier, which is connected to ground, but also relative to the cathode 27 of the tube 9, which is also connected to ground, but with the interposition of a small resistance.

The signal that goes through the receiver will always be in such a direction when rectified as to make this potential negative, and the potential will become increasingly negative the stronger the signal.

Now, when the grid 11 is made increasingly negative, the amplification in the tube 9 will be decreased. That will, then, cause the signal impressed on the rectifier after further amplification in the tube 6D6 also to become less. Furthermore, the tube 6D6 is at the same time controlled. The result is, therefore, that even though the signal strength coming into the receiver varies over a wide range, the signal as actually impressed on the detector will vary over only a narrow range.

That detector is, of course, simultaneously the signal detector and the rectifier for the automatic volume control. The result, then, is that the output from the loudspeaker as heard will vary over only a narrow range, even though the input signal strength at the antenna changes over a wide range.

Q. Professor Hazeltine, I will ask you to direct your attention, or to follow me and follow the drawing you have there while I read a paragraph from the Wheeler patent. The paragraph beginning in the second column, page 2, at line 12, and I am going to read the paragraph and ask you to follow it on this diagram Exhibit 2-B.

> "In accordance with the main feature—"

The Court: Wait a minute, will you, Mr. Davis, until I get that? I want to see what that is. Where did you say you were reading from?

Mr. Davis: It begins at line 12, the second column of page 2.

The Court: All right.

> Q. "In accordance with the main feature of the present invention the degree of amplification effected in the radio-frequency amplifying stages is automatically controlled by a biasing potential obtained by rectifying the modulated signal carrier

in a two-electrode rectifier 33, having a resistance 51 connected between the filament 38 and the anode 35 of the rectifier, through which the pulsating rectified or converted current flows, thereby developing a negative voltage at terminal 52. This negative voltage is applied over conductor 36 through the resistance 53 and the secondary winding 7 of the first radio-frequency transformer to grid 11 of the first radio-frequency stage. Resistance 53, together with blocking condenser 54, is effective to filter out and reject any audio-frequency voltages which otherwise might be applied from conductor 36 to the grid 11.''

Is that an accurate description of the arrangement in your Detrola Model 175?

A. Yes, it is accurate with one slight amendment. It refers to filament 38, and in the Detrola Model 175 the cathode is indirectly heated; and, therefore, has not the form of a filament. Otherwise, the description is precise, and in this case, of course, it is an equivalent.

Q. That is, as I understand it, that they now make tubes in which instead of having a hot filament, which is itself the cathode, they have a surface which is the cathode surface but is heated indirectly?

A. Yes.

Q. Is that right?

A. Yes.

Q. Now, will you direct your attention to the diagram offered in evidence as Plaintiff's Exhibit 3-B, which is the diagram of the Detrola Model 178, and tell us what that set is like, shortening it as much as you can by reference back to the 175. In other words, dwell more on the difference than on the similarities.

A. The two models have essentially the same system, but model 178 is simplified by certain omissions and cer-

tain simplifications in arrangement. It has the same tubes for the first three tubes. The 6A7, the 6D6, and the 75 tubes all have the same functions and essentially the same connections in both models.

In the model 178 there is no automatic tuning by a motor, so that the diode for that purpose that I referred to previously is not present in the model 178. Instead of that the two anodes 35-12 are connected together to form a single anode so that now we have only one diode and one triode in the 75 tube. The cathode 27 in the model 178 is directly connected to ground and therefore directly connected to the cathode 38 of the 75 tube. In the model 175, as I explained before, the connection is through a small resistance which is below the cathode 27 in Exhibit 2-B. The tubes connected to the loudspeaker are differently arranged in the two receivers, but that is not part of what we are particularly concerned with.

The Court: I guess we better suspend a little bit.

(Short intermission.)

The Court: In both of these diagrams, are the grounds the same, I mean the two grounds connected?

A. Oh, yes. In any of these diagrams it is customary to represent the frame or chassis of the receiver by a ground connection, and wherever you see on the diagram two grounds or a number of grounds, it means they are all connected together electrically. It simplifies the drawing of the diagram not to run lines across to show that.

The automatic volume control systems in the two receivers have the same parts and they are numbered in the same way and they function in the same way, so that I think, perhaps, it will not be necessary to repeat my previous testimony for the Model 178.

Q. You spoke, Professor, of the internal structure,

the physical structure of these tubes 75, which I understand are manufactured—that is, the 75 tubes in this set are manufactured by the Raytheon Company. Have you at hand there a diagram of this internal construction or part of it?

A. Yes, I have.

Mr. Davis: I offer this diagram in evidence as Plaintiff's Exhibit 10.

(The diagram above referred to was thereupon marked Plaintiff's Exhibit 10.)

Q. I will ask you to tell us what this diagram Exhibit 10 is and use it to describe the internal construction of these Raytheon tubes?

A. The drawing is made enlarged for the sake of clearness, and the central portion running through the axis of the drawing is a cathode sleeve which is a metal cylinder that serves as an electrical connection. Inside of that, but not shown on the drawing, is the heater element that serves to heat the active portions of the cathode elements.

There are two cathode elements represented by slightly larger cylinders. At the left we have the two diodes and each of them has a portion of a cylinder for an anode. One of them is marked "diode anode" and there is another one like it above but not marked. And inside, the cathode sleeve is covered with a coating of suitable metallic oxides to give a copious emission of electrons without having a very high temperature.

The same thing occurs in the triode section of the tube to the right. Here we have on the outside a relatively large cylinder, which is the plate or anode of the triode section. Then we have a coil of wire or helix which is the grid of the triode, and then inside of that we have a coating which forms the cathode and which is placed on the metal sleeve, so the two portions of the tube, the

diode section, which itself has two diodes, and the triode section, have nothing in common with one another, except the electrical connection through the sleeve. Their functioning is quite separate.

Q. Let me interrupt you there. On this diagram Exhibit 2-B, the two cathodes which are connected together as you have described are represented by the single inclined line marked 38. Is that right?

A. Yes. That is done for simplicity there because they are electrically connected together.

Q. Will you proceed?

A. In addition to what is shown on the drawing, there is a further electrical separation of the diodes from the triodes in the actual tube because there is interposed a metal shield around the diode section so that in addition to their physical operation they are very effectively separated electrically.

Q. Is it correct to say, or say whether or not it is correct that the two diode units are independent of each other and the triode units, except for the common cathode sleeve?

A. Yes, that is correct.

Mr. Davis: Now, if the Court please, I have here one of these tubes with the glass broken away. May I go on this way?

The Court: Yes.

Mr. Davis: (Indicating): This dot element here is a shield which conceals the anode of the triode, but inside of that is this coil, which is the grid, and inside of that again is the body of the cathode of the triode. Then, separating that from the diode structure is this shield, and this grounded (indicating), which Professor Hazeltine referred to as not being shown in the drawing, and below that hidden by another shield is this structure of two diodes; that is, the two anodes, and the

two diodes and a single cathode. If you took this down you could see the inside structure.

The Court: I see. I think I follow you.

Mr. Davis: I don't think we need put that in evidence, do you, Mr. Darby?

Mr. Darby: No.

Q. (By Mr. Davis): Professor Hazeltine, with reference to both of these sets, 175 and 178, will you tell us whether or not the arrangement is such that the potential of the diode anode, that is the potential of the rectifier anode is maintained negative relative to the amplifier filament or cathode?

A. Yes. In the normal operation of the receiver, the rectified current provides that negative potential, whether the signal is strong or weak. Furthermore, even though no signal were being impressed, there would also be a negative potential produced at the anode 12-35 by the small amount of space current that naturally flows. That is, the heated cathode admits some electrons even when there is no voltage impressed externally to carry them across to the anode. So, there would be some small negative current which would build up a negative potential on the anode 12 relative to its own cathode.

In the model 178 the cathode of the amplifier and the cathode of the rectifier are directly connected through ground.

Q. That is the cathodes 38 and 27?

A. Yes, sir.

Q. Proceed.

A. And, therefore, the potential of the anode 35-12 would also be under all conditions negative relative to the cathode 27 of the amplifier as well as cathode 38 of the rectifier.

In the model 175 what I have said applies in the same way in normal operation when a signal is being re-

ceived. When a signal is not being received, however, there is an additional effect that is inappreciable and that is due to the small resistance connected in series with the cathode 27 of tube 9. That resistance is drawn in an accentuated line directly below the cathode 27, and when the set is turned on but is not receiving signals a current will flow through that resistance in such a way as to make the connection, or make the potential of the grid 11 negative relative to the cathode 27 independently of the operation of the rectifier 33. That effect is small, and I have found that it is not noticeable when signals are being received.

Q. Now, will you direct your attention to the path through which the energy of the amplified signal passes from the amplifier 6D6 to the rectifier 33?

A. The energy passes first through a transformer whose secondary coil is drawn in heavily and marked 31. One side of that transformer goes directly to the anode 35-12 and the other side goes through the condenser tube to the cathode 38. That means, therefore, that there is a coupling from the output of the amplifier 6D6 to the diode rectifier portion of the tube 33.

Q. Now, at that place in the set the carrier, that is, the signal, is in the form of a modulated carrier wave, is it?

A. Yes.

Q. And does that connection pass not only the carrier wave but also its modulations into the rectifier?

A. Yes.

Q. Has the Detrola Model 175 a tuning indicator?

A. Yes. That is the tube marked 6G5 very close to the center of the diagram.

Q. And how is that connected to the set? Will you describe that?

A. Its input comes from the output of the amplifier.

Specifically, its input connection is made to the wire 36, there being a connection from the wire 36 down to the grid of the 6G5 tube and the potential impressed on that grid, as the automatic volume control potential changes, causes the visual indication in the form of a shadow to become wider or narrower according to the strength of the signal, which means particularly in accordance to whether it is well tuned in or not.

The Court: Suppose you come back at 2 o'clock.

(Whereupon a recess was taken until 2 o'clock P. M. of the same day, Friday, October 27, 1939.)

Detroit, Michigan,
Friday, October 27, 1939,
2 o'clock P. M.

Court met pursuant to recess.

Parties present same as before.

The Court: You may proceed.

PROFESSOR LOUIS A. HAZELTINE, was thereupon recalled as a witness herein, and having been previously duly sworn, testified further as follows:

Direct Examination (Continued)

By Mr. Davis:

Q. Mr. Hazeltine, I call attention to the fact that in the circular or pamphlet of the defendant company, Plaintiff's Exhibit 2-A, the physical values of the various elements of the set appear on the sheet of that pamphlet which contains the wiring diagram that you have discussed, and am calling attention to the fact that the resistance R8 is given as 500,000 ohms; that is the resistance that on your diagram you have marked 51, is that right?

A. Yes, that is correct.

Q. And, likewise, on the diagram, Exhibit 3-A, the corresponding resistance is shown on the diagram itself as being 500,000 ohms, is that right?

A. That is correct.

Q. Now, will you please say whether or not that is a high resistance as compared with the resistance of the diode rectifier itself?

A. Yes, it is. The resistance of a diode rectifier will depend on the range over which it is operating. But, in all cases it will be small compared with 500,000 ohms. It might be of the order of 10,000 ohms.

Q. And, will you explain the practical effect of having in the diode circuit this resistance which is high compared with the resistance of the diode itself?

A. It has the effect of making the diode a minor element in determining the current that will flow through the circuit on rectification. That is, the current that flows will depend on the voltage of the incoming signal, and on the 500,000 ohm resistance in series, but very little on the diode. That means that the operation will be linear, the current and voltage being proportional to one another. It also means that if one diode is replaced by another diode that the operation will remain essentially the same as before.

Q. That is independent of the particular characteristics of the replacing diode.

A. Yes, because those characteristics are swamped by the high value of the resistance externally.

Q. With respect to the linearity of the diode with the high resistance in the circuit in the manner shown in the Wheeler patent, will you develop a little further as to just what the practical effect of that is in the amplifying operation and the control operation?

A. Yes. A linear detector is advantageous both for

detecting the signal and for giving the rectification required for automatic volume control. In detecting the signal, the advantage is minimizing distortion. Or, perhaps, better, eliminating the type of distortion that you would get if you had a non-linear characteristic. In the automatic volume control the advantage is that the control potential that is built up will not depend on the modulation of the carrier signal so that no matter whether a loud sound is producing the modulation or whether a weak sound is producing the modulation the control that is developed will be the same.

Q. Will be proportional to what?

A. Will be proportional to the unmodulated carrier even though the carrier itself is modulated.

Q. Well, is that true whatever the strength of the carrier may be?

A. Of course, for different carriers there will be different control voltages, but for any one carrier the control voltage will depend only on the strength of the carrier and not on the strength of the modulation.

Q. And the control voltage will be proportional to the strength of the carrier itself; is that right?

A. Yes.

Q. Now, something has been said about overloading. Has this any relation to overloading of the tube?

A. Slightly, indirectly. The overloading is a characteristic that is present with a triode and is not present with a diode, but it is a somewhat independent idea from the idea of linearity.

Q. Will you state whether or not, if the three-electrode detectors were used in such a system, this automatic amplification control system, the rectified output or control potential would be proportional directly to the applied voltage or to some other power of the applied voltage?

A. With the triode systems that were in use at the

time of the Wheeler invention, the rectified voltage would be proportional to the square of the carrier and not directly.

Q. And is that an advantage or a disadvantage from the point of view of direct control?

A. That is a distinct disadvantage.

Q. Now, with reference to these two receivers of the defendants, that is Model 175 and 178, will you say with respect to both of them whether the detected signal is automatically controlled irrespective of whether the amplifier is exactly in tune with the signal carrier?

A. Yes, it is. The control is present to the degree that the signal reaches the signal detector, so that whatever comes in that may be reproduced on the loudspeaker is also there to produce the control, irrespective of whether the signal is well tuned in or not.

Q. And, will you say whether in each of these receivers the amplifier, which is connected to the rectifier, is so connected by a connection which includes a condenser in series for preventing the uni-directional components in the rectifier output from being impressed upon the input of the modulation frequency amplifier? That is a phrase in one of the claims, your Honor.

A. Yes. There is such a condenser and it functions in that way.

Q. Will you identify that condenser in each one of these diagrams, Exhibits 2-B and 3-B?

A. In Exhibit 2-B that condenser is beside the resistance 51 and connected to it on one side. It is marked in rather small letters on the original diagram as C-21. In Exhibit 3-B, the condenser is also connected to resistance 51, the connection being indicated by an arrowhead just as in Exhibit 2-B, and the notation on that condenser is a little hard to read, but there is a number that looks like O-1, and underneath it the number 200. I think that that signifies—

Q. It is .01 on the original that I have here?

A. Yes. I take that to be the capacity in microfarads and the 200 to be the voltage rating of the condenser. At any rate that will indentify it.

Q. Will you say whether or not in each of the defendant's receivers there are manually adjustable means for determining the amount of modulation frequency amplification?

A. Yes. The manually adjustable means is represented on the diagrams by the arrow-heads to which I referred in my last answers.

Mr. Davis: That is all.

Cross Examination

By Mr. Darby:

Q. Professor Hazeltine, in several of your last questions and answers you used the expression "automatic amplification control"; that means the same thing as automatic volume control, doesn't it?

A. In my answers it did, yes.

Q. Yes. As a matter of fact, automatic volume control is more or less of a derived or popular name for automatic amplification control, isn't it?

A. I wouldn't say that. The automatic volume control, as I understand it, is a perfectly proper name, and it refers to the volume of sound output.

Q. Yes.

A. Which is produced in a radio receiver. Automatic amplification control, I think may properly be used in a broader sense; that is, any control of amplification which was automatic, depending on the signal itself, irrespective of whether there was reproduction in a loudspeaker, or not.

Q. But automatic volume control, in so far as we are

concerned with it here, is effected by automatically controlling the amplification?

A. That is correct.

Q. Of an amplifier tube?

A. Yes, that is correct.

Q. So that when you have used "automatic amplification control" in the testimony that you have given, you have meant automatic volume control; you have used the two terms synonymously?

A. Yes.

Q. So there will be no confusion about that. Now, in the connections of the exhibits, Plaintiff's Exhibits 2-B and Plaintiff's Exhibits 3-B which are the diagrams you have referred to as illustrating the circuits of the defendant's receivers, the mere fact that lines cross each other is not indicative of the fact that they are electrically connected to each other; is that correct?

A. That is quite correct. An electrical connection, unless there is an error in the drawing, would be indicated always by a dot.

Q. An enlarged dot?

A. Yes.

Q. And only where those enlarged dots are is there electrical connection between the wires?

A. Yes.

Q. Now, referring to Exhibit 2-B, which is the wiring diagram of the receiver 175, where does the loudspeaker shown at the extreme right derive its modulated currents which it reproduces into sound, that is, from what part of the—it derives it from the tube marked 33 or 75, does it not?

A. Indirectly, and, of course, by that I mean that it derives its control for the modulation itself. Of course, it is understood that the power that is sent out as sound comes from the direct current source in the plate circuits

of the tubes 42, but the control of that power is from the anode of the triode section of the tube 33 or 75.

Q. So that, as I understand it, the current flowing from the top electrode, as it is pictured on the drawing of what you refer to as triode section of the tube 75, it is the current flowing through that—or from that electrode which is the current which ultimately reaches the loudspeaker in one form or another and is reconverted into sound waves; is that correct?

A. Essentially correct, except that that is not actually the current that goes over, but it is a current of that wave form.

Q. It is a current of that wave form?

A. Yes.

Q. All that I am striving to bring out, and I think there is no dispute between us, is that the actuating medium for the loudspeaker comes from what you call the anode of the triode section of tube 75?

A. Yes.

Q. And the same is true, of course, with respect to the model 178?

A. Yes.

Q. I think you made it clear, Professor, and if you have I apologize for causing you to repeat it, but the function of a condenser, as I understand it, is to permit alternating current to flow through it, but to prevent direct currents from flowing through it; is that correct?

A. That is an important function of the condenser, and the only function of a number of the condensers I have discussed here, yes.

Q. That is an important function of all condensers, so far as we are concerned with them in these circuits, isn't it?

A. Not for the tuning condensers. They are not used to block direct currents here.

Q. Then a blocking condenser is one which will block direct current but allow alternating current to pass through?

A. Yes, a condenser so used; any condenser can be so used.

Q. It is usual to refer to such a condenser as a blocking condenser when it is so used?

A. It is quite usual, yes.

Q. Now, as distinguished from that, if there is a resistance in the circuit both alternating current and direct current can flow through that resistance; is that correct?

A. They both can flow through, and they are both opposed by the resistance equally.

Q. Right. The resistance will oppose the flow of either alternating or direct current?

A. Yes.

Q. But if the current is strong enough to overcome that opposition the current will flow through?

A. That is not quite accurate, because any current will flow through, but the amount of current that flows will be proportional to the voltage and the relation will be independent of whether it is alternating or direct current.

Q. Now, with respect to Plaintiff's Exhibit 10, which is the enlarged illustrative drawing of the type 25 tube—

Mr. Davis: 75.

Q. 75, I am sorry,—does it make any difference in so far as the operation of the diode sections and the triode sections if the diode cathode or the active portion of the cathode was all one solid piece of material?

The Court: Let me hear that question.

(Question read.)

A. It might very well, because the electrons might be emitted in between the places where the correspond-

ing anodes would be, and that electron stream might not be subject to the proper control.

Q. Now, to make it perfectly clear that we are all agreed on what I am talking about, this portion that you have marked the diode cathode is actually of the same material as the portion that you have marked triode cathode, is it not?

A. I suppose it is, yes.

Q. It is the activating cathode, the activating material for the cathode?

A. Yes.

Q. Now, although they are electrically connected, as you have brought out, by both being on the same sleeve, if that activating material extended all the way in one solid piece into both of them, it is your understanding from your last testimony that it might make a difference in the separate action of the diode section and triode sections; is that your testimony?

A. It might in some degree impair the action. It wouldn't prevent the action; it wouldn't prevent the functioning, but it might impair it to some degree.

Q. I see. Do you know whether or not, as a matter of fact, 75 tubes are so constructed by some tube manufacturers?

A. I am not informed of it.

Q. You don't know?

A. No.

Mr. Darby: That is all.

Mr. Davis: That is all, Professor. Thank you.

(The witness was thereupon excused.)

Mr. Davis: May I have a word with Mr. Darby?

The Court: Yes.

Mr. Davis: You need not put this on the record. In fact, I think it would be better if we didn't.

(A discussion was thereupon had off the record.)

Mr. Davis: With that understanding, the plaintiff rests.

Mr. Adams: Yes, except for introducing some of the stipulated testimony, which I understand we are going to fix up on the findings of fact.

The Court: I understood that is all in.

Mr. Darby: Yes, and we are to enlighten your Honor as to what the subject matter is.

Mr. Adams: That is right.

Mr. Darby: At a point when your Honor cares to hear it.

The Court: There is a question here I might ask. I am not sure if the terminology is right; do I understand the carrier wave is modulated, as well as the audio wave? Do you understand what I am driving at, Mr. Davis?

Mr. Davis: I think so.

The Court: Maybe you can develop it, then, and straighten me out.

Mr. Davis: Shall I try?

The Court: You try it.

Mr. Davis: As I understand it, this carrier wave, which is a train of these very high frequency impulses coming through space is modulated in amplitude according to the sounds. That is, with audio-frequency. That is what they call the envelope of the wave. You see it pictured in little wiggles in the middle, and then a curve on top. That variation on the top is the modulation which corresponds to the sound, as I understand it.

Now, your Honor's question was, the part of your Honor's question is the carrier modulated is answered by that. Now, the thing that is separated out and goes into the audio-frequency, which is the rest of your Honor's question, is that modulation, as I understand it, taken away or recovered from, as Mr. Wheeler said, the carrier. In other words, the carrier comes along as a carrier

and the detector takes the modulation off of the vehicle and leaves the vehicle behind, and takes the modulation only into the audio-frequency.

The Court: I think I get the point. I will probably get it clear before we get through, and if I don't, I will ask you again.

Mr. Davis: Mr. Adams says quite correctly the modulation is the audio-frequency, and that is all there is in the audio-frequency amplifier, is the modulation.

The Court: I see. Do you want a few minutes?

Mr. Darby: I think we are prepared to go right ahead.

The Court: All right.

Mr. Darby: I might take this minute to tell your Honor this. This is off the record.

(Discussion off the record.)

Mr. Crews: Mr. Granger.

DEFENDANT'S PROOFS

KENNETH L. GRANGER, was thereupon called as a witness on behalf of the Defendant, having been first duly sworn, testified as follows:

Direct Examination

By Mr. Crews:

Q. Mr. Granger, what is your age?
A. 41.
Q. Will you speak more loudly?
A. 41.
Q. Your residence?
A. Ferndale, Michigan.
Q. And your occupation?
A. Employed by Detrola Radio.

Q. In what capacity?

A. Service manager.

Q. How long have you been employed by the Detrola Radio Company?

A. Nine years.

Q. As part of your duties as service manager for the company, do you keep a file of the circuits of radio sets manufactured by the company?

A. I do.

Q. Have you taken from that file certain circuits representing sets made by the company and brought them with you today?

A. I have.

Q. Will you go through those circuits that you have brought with you, and with respect to each of them tell us when the company started manufacturing that set and how long the manufacture and sale of that set continued?

The Court: Now, I wonder if you don't want to have the Exhibits marked first in order to get it in the record?

Mr. Crews: Yes, we could, or as we go along, as we refer to each one.

The Court: I have another thought here. You might be doing that marking and get ready for it while I am doing something else. We will take a little recess. The reporter will stay here and mark those for you, and you can identify them afterwards.

(Whereupon Detrola circuit diagrams were marked Defendant's Exhibits D to R inclusive.)

(The following was dictated out of the presence of the Court):

Mr. Crews: I offer in evidence the circuit diagrams produced by the witness as Defendant's Exhibits D to R, inclusive.

It is stipulated that Mr. Granger would testify as follows:

That the circuit represented by Exhibit D was manufactured by the Detrola Company, starting in August, 1932, and its manufacture and sale continued for about six months.

The circuit represented by Exhibit E was manufactured by the Detrola Company, starting in March, 1933, and that its manufacture and sale continued for about seven months.

The circuit represented by Exhibit F was manufactured by the Detrola Company, starting in September, 1933, and its manufacture and sale continued for about four months.

(At this point the Court entered the court-room.)

Mr. Crews: Your Honor, we have accomplished a good deal while you were out, because Mr. Adams has agreed to stipulate the testimony of this witness.

The Court: All right.

Mr. Crews: This will shorten it up a good deal, and in order to shorten it still further I have started dictating the stipulation.

The Court: You want a little more time?

Mr. Crews: No, I can go right on.

The Court: I sometimes think we make more progress when I stay away.

Mr. Crews: The witness produced some circuit diagrams, and as far as I have gone in the stipulation he has simply identified these three as having been the sets manufactured by the defendant.

The Court: Yes.

Mr. Crews: Manufactured starting at about the date shown on this slip and continuing for about that length of time, so I will just continue from there.

It is further stipulated that Defendant's Exhibit G represents a set manufactured by the Detrola Company. The manufacture started in the fall of 1933, and manufacture and sale continuing for about six months.

Plaintiff's Exhibit H represents a radio set manufactured by the defendant, Detrola Company, the manufacture starting in March, 1934, and the manufacture and sale continuing for about eight months.

Defendant's Exhibit I represents a set manufactured by the Detrola Company, starting in May, 1934, and the manufacture and sale continued about ten months.

Defendant's Exhibit J represents a set manufactured by the Detrola Company, starting about August 20th, 1934, and the manufacture and sale continued approximately three or four months.

Defendant's Exhibit K represents a set manufactured by the Detrola Company, starting about August 25th, 1934, and the manufacture and sale continued about six months.

Defendant's Exhibit L represents a set manufactured by the Detrola Company, starting in October, 1934, and the manufacture and sale continued about six months.

Defendant's Exhibit M represents a set manufactured by the Detrola Company starting in December, 1934, and the manufacture and sale continued about four months.

Defendant's Exhibit N represents a set manufactured by the Detrola Company, starting in January or February of 1935, and the manufacture and sale continued about nine months.

Defendant's Exhibit O represents a set manufactured by the Detrola Company starting in January, 1935, and the manufacture and sale continued for about six months.

Defendant's Exhibit P represents a set manufactured by the Detrola Company, starting in March, 1935, and the manufacture and sale continued about six months.

Defendant's Exhibit Q represents a set manufactured by the Detrola Company, starting in March, 1935, and the manufacture and sale continued about nine months.

Defendant's Exhibit R represents a set manufactured by the Detrola Company, manufactured and sold by the Detrola Company for a short period in 1931.

Mr. Adams: Let me say that that stipulation has been entered into because Mr. Crews has stated to me that that information is in accord with the circuit diagrams and dates furnished to us prior to trial as particulars, and I reserve the right to check the actual things against our own information.

Mr. Crews: Yes.

The Court: This witness, it would be possible to get this witness back?

Mr. Adams: Yes,

Mr. Crews: Yes.

The Court: Relatively easy, anyway.

Mr. Crews: This witness is in Detroit.

The Court: If you discover anything, you can make a motion to strike, and recall him.

Mr. Crews: Thank you, Mr. Granger.

(Witness excused.)

The Court: I hate to tell you that I have a Detrola set in my home, and I don't think that I have any bias potential either way in connection with that set. I also have an R. C. A. and a Stromberg-Carlson and one of the older Majestics, so—

Mr. Davis: Thoroughly biased.

The Court: Do they all happen to be in the same field?

Mr. Davis: What?

The Court: Do they all happen to be in the same field?

Mr. Davis: The same field?

The Court: Some of them are your licensees.

Mr. Darby: Some of them are.

Mr. Davis: All except Detrola.

Mr. Darby: Some of them are not. Detrola isn't.

The Court: That makes it even, then. If I don't like the political speeches that come over the Detrola, probably I get an equal number over the others.

Mr. Darby: I hope your Honor has already developed a dislike for the commercial plugs we are faced with all the time.

I recall to your Honor the fact that there is already in evidence as Defendant's Exhibit A the file history of the reissue patent and as Defendant's Exhibit B the file history of the original patent which was reissued into the patent in suit.

I would like to offer in evidence as a physical exhibit, to be available to your Honor, a copy of the printed record on appeal in the prior litigation in the Second Circuit, for your Honor's convenience.

Mr. Davis: Only to show what was before that court and not as evidence, of course.

Mr. Darby: Certainly, except in so far as the decree that was entered in that case would be available to the Court as printed in the record, but so far as the testimony or evidence is concerned, of course, it is not for that purpose.

Mr. Davis: I don't see any point in putting it in evidence at all. I have no real objection. It seems to me it is enough to identify it and leave it here.

Mr. Darby: The one respect I was trying to eliminate is the point of controversy about which we have no controversy, and that is one of the statements you made to the Court was that the record you are making in this case is radically different from the record made in the previous case, and I would like to have it available to the court to let the court make that determination.

Mr. Davis: Well, so would I.

Mr. Darby: I rather thought you would.

One of the proposed findings of fact of the plaintiff, namely, No. 29, proposed finding of fact No. 29 of plaintiff's proposals, there is no evidence in the case to support it, so we have stipulated that it is the fact that:

29. Most of the substantial manufacturers of radio receiving apparatus in the United States, including defendant, are licensed by Radio Corporation of America. Such license includes the right to use the patented inventions of Radio Corporation of America, General Electric Company, Westinghouse Electric & Manufacturing Company, American Telephone & Telegraph Co., and its subsidiaries including Western Electric Company and Bell Telephone Laboratories, Inc., among said patented inventions are the automatic volume control systems of Espenschied & Bown, Affel, Evans, Falknor, Friis, Ohl, DeBellescize, Bruce, Simonds and Carter and also the inventions of the patents to Slepiaen ~~Perry,~~ Bjornson, Heising, Green, Schelleng and Arnold, and that defendant Detrola has been licensed under the R. C. A. patents since at least September 27, 1932, which is the date of issuance of the original Wheeler patent.

Mr. Adams: I don't know when Detrola was licensed.

Mr. Darby: It was prior to that.

Mr. Davis: We will check on that, if there is any change in that date.

(Discussion off the record.)

Mr. Darby: There are a certain number of patents of the prior art which we will offer which have a filing date prior to the filing date of the Wheeler patent, but which have an issue date subsequent to the filing date of the Wheeler patent. The patentees in those cases have been pleaded as prior inventors. The purpose of the prior inventorship is the disclosure of the patent as issued. Strictly speaking, the proper proof would be of the application as filed of those inventors. We have stipulated

that the patents as issued, for the purposes of this case, may be accepted as being the same as the applications as filed, subject to any correction that counsel for the plaintiff may make.

Mr. Adams: That is right.

Mr. Darby: I offer in evidence—I will give you photostats if you haven't got them.

Mr. Adams: All right.

Mr. Darby: I offer in evidence page 1-23 of the Rider's Manual already marked as Defendant's Exhibit C for identification, namely, of the Philco Radio & Television Corporation, Model 95, and ask permission to substitute photostatic copies.

The Court: All right.

Mr. Darby: I call Mr. Kelley.

LEO A. KELLEY, was thereupon called as a witness on behalf of the Defendant herein, and having been first duly sworn, testified as follows:

Direct Examination

By Mr. Darby:

Mr. Darby: Mr. Adams has requested me to stipulate optimistically that in so far as the relevancy of this proceeding, any issues of notice and marking can be reserved until some subsequent proceeding, if any, in the case.

The Court: All right.

Q. Mr. Kelley, will you please state the qualifications of which you are possessed which fits you to testify as an expert in radio matters?

A. I graduated from the Massachusetts Institute of Technology in 1918 after pursuing a course in electrical engineering. I also received from Harvard University a similar degree in electrical engineering.

In the professional years of my training I specialized in high frequency and radio-frequency subjects. This included the theory and operation of vacuum tubes for the various purposes for which they are used, such as amplifiers, oscillators, modulators, detectors, and so on, the theory being in the classroom and the practice being in the laboratory, so that I was trained to be very familiar with the vacuum tube equipment that is used in radio-frequency work. Also, I was trained in the theory and practical operation of other radio instrumentalities, such as tuned circuits, and so on.

Immediately after graduation I joined the Signal Corps of the United States Army and spent a period of about six months, part of the time at Camp Alfredvale, New Jersey; the remainder of the time at Yale University, all of the time being engaged in signalling work, mainly radio.

In 1920 I joined the staff of the engineering department of the Western Electric Company, and remained so engaged as an engineer until 1925.

In 1925—

Q. (Interposing): What was the nature of your work while there?

A. I was going to go back after indicating what my occupation was from 1925 to 1929, because of its similarity.

In 1925, as I say, I joined the engineering department of the—that is, the department of development and research, as it is called, of the American Telephone & Telegraph Company, where I remained until 1929.

During all of this period from 1920 to 1929 I was engaged in research, development and practical field testing and operation of modulated carrier wave signalling systems both for telegraph and telephone purposes. This work, of course, included the studies of modulation and

detecting, and tuning. To mention one example, which was a project on which I worked very early in my association with the Western Electric Company, it was in connection with the Havana-Key West submarine cables, these being telephone cables, the longest telephone cables in the world.

It may seem strange if I don't explain to say that a cable a little over one hundred miles long, which these cables were, would be the longest cables of that kind in the world. I specifically mention that they are telephone cables. The cables that we generally think of connecting this country with destinations across the Atlantic or across the Pacific are of the telegraph variety.

This cable, or these cables were of a particular type in that they had iron wire wound around the central conducting core.

One of the investigations that I conducted along the putting of the equipment and the operation, the equipment that I have in mind, was carrier telegraph equipment, that is carrier wave equipment for telegraph operation on the cable, at the same time telephone speech currents would be transmitted by the cable without interference between the two simultaneous operations. The project that I speak of, in addition to getting equipment into operation, was in studying what the effect would be of carrier waves of different frequencies existing simultaneously on the conducting core of the cable in so far as modulation effects would be produced in the iron.

I just cite that as one example of the type of work that I was doing.

So, going on from 1929, at that time I was transferred to the International Telephone & Telegraph Company, more specifically the International Communications Laboratories, which was a development and research company for the International Telephone & Telegraph Company.

While there I developed a special type of carrier wave, modulated carrier wave, telegraph system for application to telegraph circuits which had different characteristics from the telephone circuits on which I had previously worked.

I remained there until 1932, and from 1932 until now I have been engaged in consulting engineering work, mainly connected with communications and radio.

In recent years I have testified on a number of times as a patent expert in radio litigation; for example, I testified in the Radio Corporation of America, the Mackay Radio & Telegraph Company, the subject matter there being the short-wave directional antenna systems, together with means of supplying the short-wave energy from a remote station to those directional short-wave antenna systems. These antenna systems are used for the transmission of commercial telegraph, radio telegraph messages to points covering the entire world.

I also testified in the Philadelphia Storage Battery Company, better known as Philco, the Radio Corporation of America, with respect to the meaning of the technical terms used in a license agreement between those two parties.

I have testified a number of times in the Exchequer Court in Canada as a patent expert on matters of a radio nature. I have also published technical articles in engineering magazines; presented a number of technical papers before the professional society, and I delivered a number of lectures at the Massachusetts Institute of Technology on a subject matter which is very closely associated with radio, namely, on a new theory and method of design of tuned and electric wave filter circuits.

Q. In connection with this, which you referred to as carrier wave on a cable, is that what is sometimes popularly referred to as wired wireless?

A. Yes, I think the public generally thinks of it as wired wireless, and that is the popular term.

Q. And, it is an application of principles of wireless to wire communication?

A. Precisely.

Q. And both of them are carried on simultaneously?

A. That is right.

Q. Are you ~~familiar with~~ the original Wheeler patent 1879863 and its reissue here in suit, No. 19744?

A. Yes, sir.

Q. I notice that the reissue patent states on page 1, line 9, and following that: "the present invention provides means for effecting automatic amplification control." Do you accept that as a correct technical description of what we have referred to in this case as automatic volume control?

A. Yes, sir.

Q. And what are as you understand it, the essentials of automatic amplification control?

A. The essentials of automatic amplification control are as follows: First there must be something to control. In this case it has been the modulated carrier wave or the resulting speech and music from that carrier wave. In the second place, there must be an instrumentality, such as the amplifier which does amplify to control that thing. And, in addition to that, the actual means of controlling.

Q. Now, referring to the original Wheeler patent, is there shown more than one way of effecting automatic amplification control in that patent?

A. Well, I would say that certainly in one sense there is shown in that patent only one way. There are different instrumentalities used in certain of the figures to illustrate.

Q. And what is that one kind?

A. That one way is by controlling the amount of negative grid bias on the controlled amplifier or amplifier tubes.

Q. Do you agree with Mr. Wheeler that it was known for many years that you could control the amplification of an amplifier tube by controlling the negative bias on the grid electrode?

A. Oh, yes.

Q. That was known many years prior to 1925?

A. Yes. I am quite sure of that.

Q. Now, you say that the original patent shows a number of different amplifications of the one way disclosed by the patent of effecting automatic amplification control?

A. Yes.

Q. Will you point out the different exemplifications?

A. I believe I can group them. Figure 1.

Q. This is of the original patent?

A. That is what I am looking at.

Q. Yes.

A. Figure 1, Figure 3. Figure 1 and Figure 3 exemplify this automatic amplification control using a triode connected as a diode as the instrument or one of the cooperating means.

Q. And what do the other figures illustrate?

A. Figures 4 and 6 utilize, instead of the triode connected as a diode, a triode connected as such, that is, as a triode.

Q. What does the patent teach as to the use of one as distinguished from the other?

A. Well, the patent teaches that in some conditions it is advantageous to use one and in other instances it is advantageous to use the other. The particular reference I have in the specification which leads me to say that occurs on page 8, really in two places, page 8 beginning at line 70, where the statement is made:

"The three-electrode detector is useful for relatively small applied voltages, and the rectified output voltage is then approximately proportional to the square of the applied voltage, i.e., to the power associated with the applied voltage."

And then further on down the page, beginning again at line 105:

"On the other hand, the latter type of detector"—

Referring there to the three-electrode type of detector.

"—the latter type of detector is more sensitive because it is also an amplifier, so that the control system operates on a smaller applied alternating voltage."

So, to put it in other words, if the system in which the automatic amplification control is to be introduced is one in which the amplification is inadequate, or, at least, not easy to obtain, so that when the signals, the modulated signals reaching the detector are not very large, then it is advantageous to use the three-electrode type of detector for the reason that the three-electrode type of detector also amplifies, therefore it can take care of a smaller signal applied to it.

On the other hand, if there is a plentitude of amplification, in other words, if the amplification is easy or cheap to secure, preceding the detector, then it will be a relatively easy matter under those conditions to apply a large signal voltage to the detector in which case the two-electrode or diode type of detector would be preferable, the preference there being of a two-fold nature: One, is that while it does not amplify, and, in that respect it is not an advantage, it doesn't require the extra batteries of the three-electrode detector, and it can be made to be more linear than the three-electrode detector.

I don't mean by that that the three-electrode detector

cannot be made to give a substantial linear characteristic, but only that the possibilities of the two-electrode detector are somewhat superior in that respect.

Q. Now, what type of signal was available to radio broadcasting receivers, say in about 1928 or 1929, with respect to their strength?

A. I don't have any figures on it, but my recollection is that there has been a continual increase in the amount of power radiated from the antennas of these broadcasting stations. I have in mind one development which is of a fairly recent nature, showing the increase in power radiated by the antennas of the broadcasting stations, namely, I refer to the renovation of Station WOR in recent years, where the power of the radio waves was not only increased, by increasing the energy supplied to the antenna, but was also made somewhat directional, so that a large number of users of radio receiving sets could enjoy the benefit of a stronger signal at the point of reception. What this would mean in terms of what we are now speaking of is that it would make it less necessary to secure a large amount of amplification for the more recent developments in broadcasting practice.

Q. Now, with respect to the receivers themselves, has there been any change in the per-unit or the per-tube amplification in the receivers?

A. Well, there has been rather remarkable changes in the receivers due to a large extent, although not entirely, to improvement in the manufacture of vacuum tubes, both with respect to the quality of the tubes themselves and the design of the tubes with respect to the number and arrangement—the number and arrangement of the electrodes in the tubes.

For instance, the screen grid tube has already been mentioned, and my recollection, I think, coincides pretty much with what I have heard already stated, that that

came into popular use, or rather widespread use about 1929.

Dwelling on the screen grid tube for just a moment, the screen grid tube made it possible to secure greater and more stable amplification, particularly in the amplification of frequencies in the nature of radio frequencies, that is, about a million cycles or so per second, as well as of intermediate frequencies.

It had this great advantage. In the first place, because the screen grid immediately abolished one difficulty that had been had in the amplification of radio frequencies, namely, the tendency of a three-electrode tube to fight itself, so to speak, by returning energy from the output circuit to the input circuit with disadvantageous results. Sometimes the main difficulty was to prevent the tube from breaking out into oscillation.

I believe Professor Hazeltine has already mentioned in connection with his own experience that he evolved a system of neutralization which was for the purpose of overcoming, as far as practicable, the effects of that. That was a hindrance to amplification with the triode at very high frequencies.

Also, the amplification factor of a triode was rather low. The 201-A tube which Mr. Wheeler mentions in his patent, by way of exemplification, for example, has an amplification factor of 8. That is eight times. That does not mean that you get magnification, let us say, of the voltage of the signal of eight times going from input to output, but it does measure, in a way the maximum possibilities through the tube itself. Additional step-up in voltage can be obtained in the circuit interconnecting the tubes so that the amplification per stage, including the tube and the coupling unit, would be of rather modest value, whereas coming to the screen grid tube, the introduction of the screen grid, besides stabilizing the amplification of the tube in the circuits to which it was con-

nected, also, has one effect, produced a very large amplification factor so that the amplification factor there would be well in excess of one hundred times, many of the tubes having amplification factors of 400 or 500, and so on, times.

In the use of the screen grid tubes full effect was not given to all of this amplification factor, but by virtue of a number of very desirable characteristics, for instance, the mutual—what is called the mutual conductance of the tube, which is often called a figure of merit for this reason, that it indicates how useful the tubes can be in the way of amplification, the mutual conductance or figure of merit is more than doubled over the triode. And there is the lack of necessity for the neutralizing, the stability of the amplification, so that you could go very high in it. And, in addition to that, a rather important factor in connection with the amplification of very high or radio-frequency currents was that the plate impedence I believe, the dynamic plate impedence was so high that it had very little effect of a harmful nature on the tuned circuit.

Q. What do you mean by "plate impedence"?

A. Well, in this instance I mean the equivalent plate impedence which is really an attempt to simplify the operation of the tube.

Q. But, I mean what do you mean by the term "plate impedence"?

A. I mean by the term "plate impedence" that if I substituted for the tube a generator of some sort which would produce exactly the same voltage that the tube is producing when it is functioning, and has the internal impedence of the tube, then that could be substituted for the tube for the purposes of analysis.

Q. Maybe the court knows what you mean, in the electrical sense, when you say "impedence", but for fear

that the court might not know, would you please tell us very briefly what you mean by "impedence"?

A. Well, impedence is the name that suggests an opposition. That is, if a voltage is applied to, let us say, a resistance, which is one kind of impedence, and that voltage we will say, now, is a battery, an ordinary battery, the current which would flow through the resistance, we will say, is of a certain amount. If, however, I make that resistance twice as great, then only half of the current that formerly flowed through the resistance will now flow through it. There was an increase in the opposition to the flow of the current.

There are other forms of impedence, but generally speaking they represent opposition to the flow of current when a generator of a voltage is applied across them.

Q. Now, you heard the testimony of Mr. Wheeler that at the outset some of the licensees of the Hazeltine Corporation, when they brought out an automatic volume control, or automatic amplification control device, they utilized the triode type, which is one of the two types disclosed by his patent. Having in mind the apparatus and equipment available at that time, can you, from an engineering point of view, explain why a triode type was used in preference to the diode type?

A. Well, in those days amplification was not so easy to secure, and the triode type of rectifier would operate with a smaller signal applied to it. Consequently, it didn't require additional amplification. Whereas, the two-electrode, or diode type, would require quite a little more.

Q. And, what relation, if any, did the advent of the screen grid tube have to the adoption of the diode type?

A. I think it had a great deal to do with it, because it made the amplification which was necessary to get the high signal voltage that must be applied to a diode in order to get the linear rectification, it made it available.

Q. And, if you were to attempt to duplicate the power amplification, or at least the amplification, which has been made possible by means of a screen grid tube, could you estimate how many additional tubes would be required for that purpose in order to be able to use the diode type?

A. Well, it would be a little difficult to estimate the exact number of tubes, not having the tubes themselves in the circuits, but I believe that the number of tubes which were used in connection with Mr. Wheeler's experiments are indicative of the number of extra tubes that would be required.

I might say that you might refer in that respect to the number of tubes that are used, for instance, in the accused receivers, being—(referring to notes)—in the 178, which I believe is referred to as Plaintiff's Exhibit 3, four tubes; and, in the 175 type receiver, which is Plaintiff's Exhibit 2, six tubes.

Q. Has there been any change in the cost of the tubes? In other words, has there been any steady decrease in the cost of the tubes throughout the years?

A. There has been a decline in the cost of the tubes. The price one would have to pay for these tubes, so they become less and less expensive.

Q. Now, will you refer to the reissue patent, and I call your attention particularly to the paragraph beginning on page 4 in the first column, line 57. Will you translate that into simple understandable language and comment on it in so far as it has a bearing on the issues here presented?

A. Well, I don't know if you wish me to read it into the record first.

Q. That won't be necessary.

A. That won't be necessary?

Q. No.

A. Well, that paragraph, in general, is dealing with the advantages of the two-electrode type of rectification,

which is said to give a linear type of rectification, as contrasted with the use of a three-electrode detector.

The general contrast that is brought out there is to the effect that with the two-electrode type of detector it is possible to get lineal rectification. With the three-electrode type of detector only square law type of rectification is obtainable, and as it produces a form of distortion it is, therefore, undesirable.

I think I should clear that point up somewhat, because in my experience it doesn't fully tell the story.

I think I can best do that by first telling what my understanding is of square law detection. Square law detection, I think, can be most simply explained in terms of the size of the signal which is being detected.

All detectors have a characteristic which, if measured with steadily applied voltages reading the amount of current passed by the detector, will not be proportional, that is, they will not form a straight line. For instance, if one volt is applied, let us say, and a certain current is read as the current passing through the detector, it will not follow that if two volts are applied, then two units of current will flow through. Quite to the contrary there is a disproportion between the steady voltage applied and the resulting current responding to those steady voltages, and that is characteristic of all detectors having curvatures of varying degrees.

Well, in square law detection a small signal must be applied, or square law detection cannot possibly be obtained, whether it is in connection with a diode, that is a two-electrode rectifier, or a rectifier of the three-electrode type. The reason I say that is this; the term "square law" as used in this connection is the result of a mathematical analysis of what takes place during detection of small signals, and it proceeds along these lines, without going into it too deeply, all I want to do is to indicate the origin of the term.

The static characteristic, which was what I was describing when I was speaking of applying steady voltages and observing the resulting current, the curve obtained by plotting those values of current against voltage can be represented by a mathematical equation. The methods of doing that are well known to engineers.

The way of determining what happens when an alternating current, or signal current of an alternating nature, such as we are speaking of here, is applied to the detector, a mathematical artifice is used which is called a Taylor series of expansion.

I don't expect to be understood what I mean by that on the record; I simply say it for the sake of preciseness, but I will say this; it is supposed to represent the end result of applying the signal voltage to the detector in terms of a large number of individual products which are added up to get at some total.

One of the characteristics of the products of the terms that are added up is this, that one is what is called a linear term; another one is what is called a square term; the next one a cube term. Now, we can readily see that if a quantity is relatively small, if you square it you get something considerably smaller; if you cube it you get something considerably smaller than that. For example, take one-tenth, if you square that you have one one-hundredth. That is small compared to one-tenth. And, if you cube it you get one one-thousandth.

Now, the reason why the small signal voltage applied operates a detector according to the square law is that because of this reason the diminishing value of a small signal as you square, and cube, and so on, enables you to say, "Well, when I get beyond the square term I can throw all the rest away, because it is too small." And, that is the origin, as I understand it, of the term "square law detection."

So that, inevitably square law detection is bound up with small signal voltages applied to it, and that is true whether we are concerned with two-electrode or three-electrode type of rectifier.

Now, when, on the other hand, we are concerned with the amplification of large signal voltages, the so-called square law detection no longer applies; and neither, may I say, does the result of linear detection immediately follow simply because the signal voltage we are now considering is so much greater that it cannot possibly follow the square law. But, I do mean that there is a transition from one to the other, and in order to obtain linear rectification, we, first of all, must have relatively large signal voltages applied to the detecting device.

Those relatively large signals, however, are much larger for the two-electrode type of rectifier than they are for the three-electrode type of rectifier for the reasons I have already stated. The three-electrode type of rectifier also amplifies at the same time it rectifies.

So that where the statement is made in the specification of the patent in suit, which is the re-issue patent, on page 4, column 2, line 8, where it states:

> "If a three-electrode detector were used in an automatic amplification control system, the rectified output voltage would be approximately proportional to the square of the applied voltage, i. e., to the power associated with the applied voltage."

The exception I take to that statement is that that would apply only under special conditions of low signal detection.

It is quite possible, and it is done, to use three-electrode detectors for what is called power detection. Now, power detection is a term which is used when a three-electrode

device is used for detecting large signal voltages and a three-electrode tube, properly connected, properly equipped with the right plate and grid potentials and associated circuits, and a substantially linear rectification results, and a result which is adequate as far as range of voltage that is developed is concerned for the purposes of automatic amplification control over a substantial portion of linear characteristics.

Q. Is it your opinion, then, that the Wheeler patent is in error in citing this as a disadvantage of three-electrode or triode automatic amplification control?

A. Yes. That is the reason. That is what I was attempting to explain.

Q. With that disadvantage deleted, what remaining disadvantages, if any, of the triode automatic amplification control remains as disclosed by the patent?

A. The necessity for the use of an additional battery in the plate circuit for furnishing the power for the plate circuit.

Q. When you say the use of an additional battery, do you mean an additional physical battery as a physical thing, or an additional drain on the B-battery that usually supplies all the plate grids.

A. No. What I mean is this: Using the term "battery", that is a hang-over from the days when batteries were used as such. But since prior to 1926 or 1927, if I remember correctly, the radio receiving sets have no longer used batteries as such, but have secured their power that the batteries formerly supplied by plugging into the house lighting circuit the same as you plug in a table lamp or something of the sort, an electrical appliance.

Q. So that instead of actually needing an additional battery, all it means is that there must be an additional current, an additional amount of current taken off of the electric light line?

A. I prefer to say that it would involve the provision of an additional voltage for that purpose in with the rest of the power supply.

Q. Taken from the—

A. (Interrupting): Taken from the common power supply; that is right.

Q. Now, I would like to go back just a minute to the screen grid tube proposition. When you talk about the necessity for neutralization due to interaction between the circuits of the old amplifier tubes prior to the advent of the screen grid tubes, that interaction took place in part and largely right within the vacuum tube itself, didn't it?

A. That is right, and it was because of that that the action took place. That is, the exposure, if I may put it that way—

Q. Yes.

A. (Continuing)—of the grid electrode which was in between the filament and the plate, the exposure of that grid electrode to the plate was essentially the reason for all this trouble.

Q. Now, I would like to take you to a new subject, Mr. Kelley.

Detroit, Michigan.
Saturday, October 28, 1939.
9:30 o'clock A. M.

Court met pursuant to adjournment.

LEO A. KELLEY, was thereupon called as a witness herein, and having been previously duly sworn, testified further as follows:

Direct Examination (Continued)

By Mr. Darby:

Mr. Darby: At this time, your Honor, I would like to offer in evidence the folder of prior art patents that I have given to your Honor.

The Court: All right.

Mr. Darby: As Defendant's Exhibit T.

Mr. Darby: I might state to your Honor, so that you will not be alarmed by the number of patents in this prior art folder, we are going to refer to very few. The case as now presented doesn't claim for Wheeler automatic volume control per se, as your Honor has undoubtedly gathered. Many of those patents show automatic volume control with arrangements which were pertinent in the prior decisions because of the claims there made, which are not pertinent in the present case because of the claims here made, and the concession that automatic volume control was old, as such was old, so that but brief reference will be made to them.

Q. Now, Mr. Kelley, at the adjournment yesterday you had pointed out that the original Wheeler patent disclosed two automatic amplification control systems, one with the diode and one with the triode, and that the reissue patent is confined to a diode, an automatic volume control or automatic amplification control system, and that the patent pointed out the advantages and disadvantages of triode as distinguished from diode. I believe you had also pointed out that one of the disadvantages that Mr. Wheeler stated in his patent was the linearity of a diode as a rectifier. Now, I want to crystallize that subject with just a few questions and then we can proceed.

Is linearity a desirable feature with a triode?

A. Yes, sir.

Q. Next, is linearity obtainable with a triode?

A. Yes, sir.

Q. And to that extent was Mr. Wheeler's statement in his patent erroneous?

A. In my opinion, yes, sir.

Q. And with that disadvantage of the triode disregarded, what practical disadvantage was there in using a triode as distinguished from the diode for automatic amplification control?

A. From a dollars and cents point of view, the additional battery or the equivalent of a battery would, in receivers which employ the alternating current of the house lighting circuit for operation, amount to a difference of a very small fraction of a penny for an evening's entertainment. In other words, an infinitesimal increase in the expense of operation.

Q. Now, was this linear characteristic of a diode original with Mr. Wheeler, or the discovery of its linear characteristic?

A. No, sir.

Q. Will you please very briefly refer to an instance of the prior art where it was covered?

A. It was covered in the patent to Armstrong, No. 1716573.

Armstrong in this patent is describing a signalling system, in which he desires to use a linear rectifier for a particular purpose. In connection with the description of the system, he gives a very complete explanation of just how to obtain linear rectification, using a diode. I think reference to figure 2 would enable me to show it more simply on the figures. In the left hand—

The Court (Interposing): Just a moment, Mr. Kelley. I haven't Figure 2.

A. Figure 2 is on the last page, your Honor.

The Court: I have it now.

A. Looking at that figure, particularly the left-hand

side of that figure, the No. 37 indicates a diode rectifier. The number 35 indicates a high resistance connected in series with that diode. The transformer,—that is, the two coils together just to the right of 35 and 37, numbered 33, is the coupling circuit for feeding the modulated carrier wave signals to the rectifier circuit. In the specification, referring to these elements 35, the resistance, and 37, and their manner of connection, Armstrong gives a very complete and clear explanation of how he is to obtain the linear rectification. On page 2, beginning at line 116, he says:

> "In accordance with the present invention, the difficulties above described are overcome, and the balancing operation carried out with a practical rectifier with the same degree of efficiency as could be obtained by the ideal rectifier. To this end a large resistance is inserted in series with each of the rectifiers. This straightens out"—

That is, it makes linear—

> "—this straightens out and alters the characteristic of the rectifier after a certain initial electromotive force has been impressed thereupon and makes it approach the ideal rectifier.
>
> "Secondly, the incoming signals are amplified sufficiently"—

Thus stressing the necessity of large signal voltage to be applied to the rectifier—

> "—so that the initial bend in the rectifier characteristic is passed and rectification takes place on that part of the characteristic curve which approximates the ideal."

The ideal, he has explained, is a straight line, which is synonymous with "linear". Then he describes the instrumentalities more in detail on page 3, beginning with line 18:

"It is advisable to use rectifiers of the valve type,"—that is, the vacuum tube type—"preferably, the Fleming valve or two element vacuum tube. The resistance used in series with the rectifiers or detectors may be from 100,000 to 200,000 ohms. Extremely high amplification is necessary to produce an electromotive force of one or two volts across the detectors and resistances, and for this purpose six to ten stages of vacuum tube amplification may be necessary. It is also very important that the last stages of the amplifier should be composed of tubes capable of handling considerable power to prevent blocking or wiping out of the signal by disturbing impulses of large amplitude."

In this passage, he says that it is desirable to use a two-element vacuum tube for the detector; that is, a diode. Also, that a large resistance, the value of which he indicates should be from 100,000 to 200,000 ohms in series with that two-electrode rectifier; also that it is necessary, in order to obtain this linear characteristic, to employ large signal voltages, and in order to obtain them, a large amount of amplification is necessary preceding the detector, and that the vacuum tubes themselves that feed into the detectors should be capable of handling large signal voltages.

Q. And until the screen grid type of tube amplifier became available on the market, what was the only expedient available to obtain the large amount of voltage necessary to be able to use a diode type of rectifier?

A. It would be necessary under those conditions to use a large number of stages, that is, vacuum tubes for amplifiers, of the three-electrode type, in order to obtain a sufficiently large output voltage.

Q. Now, I think you crystallized yesterday, again referring to the two types of automatic volume control dis-

closed by the original Wheeler patent, that is, the triode and the diode, that they both had one thing in common, namely, an amplifier and a detector which develops a voltage to control the amplifier, is that right?

A. That is correct, sir.

Q. And that in both types a high resistance was used in connection with the detector to develop the voltage necessary for control of the amplifier?

A. Yes, sir.

Q. Is that correct?

A. Yes, sir.

Q. Now, what is used in all types of automatic amplification control for that purpose?

A. Just precisely that; in other words, a detector—first, there is the control,—the amplifier, which is to be controlled, a rectifier or detector in which circuit a high resistance is necessary for the purpose of developing a voltage, which is then applied back to control the amplifier.

Q. Then, am I correct in understanding that the use of a resistance is universal in all types of automatic amplification control to develop the voltage necessary to control the amplification?

A. So far as I am aware, it is.

Q. Now, will you refer to the instances of the prior art, typical instances illustrating this, and I would suggest that you refer first to the Evans patents.

A. Referring to the Evans patent, the patent number being 1736852, this patent discloses what is called a power line signalling system. That is a carrier wave, a modulated carrier wave signalling system.

The figures show a large amount of apparatus in which we are not interested, most of which we are not interested in at all, but referring to Figure 1, the part in which we are interested is in the receiving circuit which

is at the lower part of the figure, near the center, generally in the vicinity of Nos. 15 and 16, where there seem to be three three-electrode vacuum tubes side by side.

This figure, or this part of the figure, is separated out and forms a part of a division which is—this part forms the entire circuit of the device which is in the other Evans patent. And with this brief explanation of the first Evans patent, I will now immediately proceed to the second Evans patent, showing and describing in detail that portion of the circuit to which I just referred in the previous one.

The Evans patent to which I am now referring is No. 1869323.

Referring to the figure, I believe it would simplify matters if I gave a rather general description first and then proceeded to details. Unlike a great many of the circuits that are shown, the progression of events in this drawing is from right to left instead of from left to right. In other words, looking at the extreme right-hand portion of the drawing, where the numerals 1 and 2 indicate the ends of two lines connected to a coil, the modulated carrier wave signal enters this circuit by those two terminals. That is where everything begins.

The signal is then passed through a transformer 6, amplified in the tube 5, a three-electrode amplifier, through the transformer 7, through the second amplifier 4, and thence through the transformer 9 to the amplifier detector 8, and from the amplifier detector in two separate ways,—

And one way through the transformer 10, and thence out beyond the ends of those broken lines to a telephone receiver, which corresponds to the loudspeaker in a radio receiving set.

The other path taken from the detector amplifier 8 is downward through the circuit which I will describe

a little more in detail later for the purpose of developing automatic amplification control voltage, which is applied then to the amplifiers 4 and 5 for the purpose of automatic amplification control.

Thus the detector amplifier 8 performs the dual function of detecting the signal, that is, the speech, and at the same time providing the current which develops the automatic amplification control voltage, that is, it performs the two functions in one tube.

Q. And that voltage is utilized on the grids of both of the amplifier tubes?

A. That is right. And, in order to make that plain from the circuit, it can be very easily traced out.

The Court: I think I followed it all right now. Is it your thought that this is exactly the same as the Wheeler system?

A. It is my thought, your Honor, that this is the same as the Wheeler system except that he uses a triode rectifier instead of a diode. Although in the specification where Evans refers to the device which is No. 8, and which is shown in the drawing as a triode, he refers to it in the specification on page 1 at line 81 as:

> "A detector or rectifier space discharge device 8 is connected to the output circuit of the space discharge device 4 by means of a transformer 9."

Now, that means to me that the function that he wanted performed there was detection and that it was well known at that time that not only would a triode provide that detection with amplification, but also so would a two-element tube or a diode.

Mr. Darby: Does that answer your Honor's question? I don't want to interrupt.

The Court: I was going to ask another question. I

guess you both would object to it on the ground I was invading my own province.

Mr. Darby: I might say, your Honor, that those facts raise the two issues. One is whether or not this is not a complete anticipation of the identical thing, because it says a detector or rectifier, whatever the term was, and a space discharge—or a space discharge device.

It also raises the second question whether or not, if everything else is exactly the same, any invention was involved in changing a diode instead of a triode, which, I think, will become crystallized by further questions.

The Court: The question you would like to ask the witness, whether a person skilled in this art wouldn't have, without exercising any inventive genius, substituted a diode for a triode?

Mr. Darby: I will ask him that question.

The Court: I think about that time Mr. Davis is going to object.

Mr. Darby: I don't know whether he would or not. I don't believe he would. I think it is within the province—

Mr. Davis (Interposing): The only reason I wouldn't is that I am not very much concerned in what the witness' opinion is.

The Court: All right. That makes us even, I guess.

Mr. Darby: That makes it easier.

Q. Where was the passage?

A. The passage to which I referred was page 1, beginning at line 81.

Q. Page 1, line 81. What does the term detector or space discharge device mean to one skilled in the art?

A. A space discharge device means to one skilled in the art a device which has a cathode for the emission of electrons in an evacuated space in which there are one or more electrodes associated with the cathode.

Q. And, what was a detector to one skilled in the art at the date of this application, 1923? What was a detector? What detectors were available to those skilled in the art?

A. The two-elements vacuum tube, the three-element vacuum tube; that is, the diode and triode. There were all kinds of mineral types of detectors, galena, for example, and electrical detectors, and so forth.

Q. Confine yourself to the vacuum tubes. What vacuum tube detectors were known to the art at that time?

A. Well, the diode and the triode either with or without gas inside the envelope.

Q. In the Armstrong patent to which you made reference a little while ago, reference was made to a Fleming valve. Was that an instrumentality well known in the art in 1923?

A. Yes. It preceded in point of time the three-element tube.

Q. And, what was its use as for radio purposes?

A. It was used for a detector.

Q. And that was well known by all engineers in the art?

A. Yes, sir.

Q. Then, I will ask you the question, in your opinion —first, I will ask you was the language which you have quoted from the Evans patent in your opinion a direction to those skilled in the art to use either a two-electrode device or a three-electrode device?

A. Yes, sir.

Q. It was a direction?

A. Yes, sir.

Q. If by any possible interpretation it was not a direction would it have required inventive ingenuity, in your opinion, in 1923 to substitute the well known two-electrode Fleming valve for the three-electrode device in the Evans circuit?

Mr. Davis: I will object.

A. Not at all.

Mr. Darby: You do object?

Mr. Davis: Yes.

The Court: Sustain the objection.

Mr. Darby: All right. My prediction was erroneous, as was Mr. Davis'.

Mr. Davis: I said "If I didn't."

Mr. Darby: All right.

Q. Now, I am interested in the circuit arrangement employed by Evans to obtain automatic amplification control. Will you please point out what in that circuit—first, point out the automatic amplification control circuit?

A. Yes, sir. As stated previously, the tube 8 performs the dual function of supplying the audio-frequency or demodulated signal to the telephone receiver, and also to supply the automatic volume control voltage. It does the latter in the following way:

Starting with the plate electrode of 2-8, which is the rather small narrow rectangle on the left of the three elements, following that line upward and horizontally to the left under one of the coils of the transformer 10, through that coil, proceeding straight on down through the switch 12, and the switch 13, which in the drawing is shown open, but which in use is closed, and then down to the bottom of that line horizontally to the right a short distance; then vertically upwards to the junction point of a horizontal line. Thence to the right through the battery 16, to the junction point with the minus sign very close to it, and then directly down through the resistance 19 to the junction point near the plus sign on the bottom horizontal line, and thence to the left on that bottom horizontal line to the junction point of a vertical line, and then by a vertical line downwards a short distance to a symbol which indicates a ground

connection, thus connecting the plate circuit through these elements, just connecting the plate of the vacuum tube 8 through the elements which I have traced out to the filament or cathode circuit.

The resistance 19 connected directly in parallel or across it the condenser 21. Those two elements together, that is the resistance 19 and the condenser 21 cooperate in the following manner:

The condenser 21 by-passes or shunts around the resistance 19 all of the high frequency signal component that may be in that circuit, leaving only the direct current component to flow through the resistance 19. This direct current or rectified direct current flowing through the resistance 19 from the upper to the lower end, or rather, from the lower end to the upper end, produces a negative voltage at the upper end with respect to the cathodes or filaments of the vacuum tubes. This negative voltage at the upper end of 19 is under the control of the incoming signal, becoming increasingly negative as the signal increases.

This negative potential, this negative voltage, is applied to grids of tubes 4 and 5 in the following manner:

Starting at the junction point with the minus sign very close to it and proceeding to the right, passing through the resistance 20, through the battery 18, and straight on in a horizontal direction and around the bend upward through the left-hand coil or transformer 6, thence horizontally to the left and downward to the middle element of the amplifier tube 5, this middle element being indicated by a zig-zag line, the controlled grid of that amplifier tube. At the same time this controlled voltage is also applied to the grid of amplifier 4 in the following manner:

The circuit from the negative end of resistance 19 through 20-18 to a large dot which indicates a junction

point, and at that junction point going upwards through the left-hand coil of transformer 7, then horizontally to the left and downwards to the middle or grid electrode of amplifier No. 4.

In this circuit there is the resistance 20. There is also the condenser 22. These two together, comprise a time constant filter of the resistance capacity type of precisely the same type as described in the Wheeler patent. So that by these circuits which I have traced out, if the signal is large there is an increase in the negative voltage applied to the grids of 4 and 5, thereby automatically controlling their amplification. And likewise in the reverse sense, if the signal is small, there is a decrease in the negative voltage applied to the control grids of amplifiers 4 and 5 to regulate the amplification automatically.

I think I should refer to some of the passages in the specification which touch upon these points. For instance, the time constant filter which I just spoke of is referred to in the specification on page 1, beginning at line 55:

> "A filter element comprising condenser and resistance elements is connected across the gain control resistance element for shunting speech frequency variations to prevent the amplifier tubes from setting up spurious oscillations."

And the functioning of the automatic control by means of changing the negative grid bias is referred to in the specification on page 1, line 48:

> "The resistance element"—that is 19—"thus impresses a potential on the grids of the amplifier tubes, which varies according to the output from the rectifier or detector tube."

And a more detailed description of that resistance element 19 is given on page 2, and I think it would be

even better to refer to that passage, beginning on page 2 at line 11:

"A resistance element 19 in the output circuit of the detector or rectifier space discharge device is also included in the grid circuits of the space discharge devices 4 and 5. Thus a negative potential is impressed on the grids of the discharge devices 4 and 5 which varies in accordance with the space current of the detector or rectifier space discharge device. A filter comprising a resistance element 20 and condensers 21 and 22 is connected across the resistance element 19 for shunting voice frequency variations to prevent the amplifier 3 and the detector or rectifier acting as an oscillation generator. The filter insures against the generation of spurious oscillations which would cause the so-called 'singing'. The filter also serves to adjust the time constant of the circuit to the desired value."

The adjustment of the time constant is a rather simple matter, since it involves, with a given condenser and a given resistance, merely multiplying the resistance by the value of the condenser.

The Court: Was that Evans patent cited in the Patent Office?

Mr. Adams: The earlier Evans patent with the identical disclosure was cited during the prosecution of the original patent.

The Court: You are not in disagreement. Mr. Darby says it was not cited at the time the reissue was up.

Mr. Adams: That is right.

A. Then I have one other reference I would like to make to the specification of the Evans patent. On page 2, at line 60; he there sums up the operation in the following words:

"It is thus apparent that an increase in the

space current of the detector or rectifier discharge device 8 will increase the negative potential impressed on the grids of the amplifier discharge devices 4 and 5. This will serve to reduce the amplitude of the waves supplied to the detector or rectifier discharge devices and accordingly control the power supplied to the operator's telephone set."

Q. (By. Mr. Darby): Now, will you please compare the automatic amplification control circuit of this patent with the similar circuit of the Wheeler patent?

The Court: I wonder if it would make any difference if you would start this way: Compare the Evans circuit with the first claim.

Mr. Darby: The first claim of the Wheeler patent?

The Court: Of the Wheeler patent.

Mr. Darby: That will be all right.

The Court: Instead of comparing the drawings?

Mr. Darby: We will be glad to do that.

Q. (By Mr. Darby): Do you find in the Evans patent a signal receiver having a carrier frequency amplifier which includes at least one vacuum tube having a cathode and control electrode?

A. Yes, sir; substantially as I have described.

Q. Do you find in the Evans patent a two-electrode rectifier coupled to the output circuit of the amplifier, having in mind the testimony you have given as to the instructions to have a detector or space discharge device?

A. It is shown three-electrode in the drawing, but in the specification the instructions include, in my opinion, the use of the two-element or two-electrode rectifier.

Q. Do you find a high resistance connected between the rectifier anode and the amplifier cathode? And, if so, point it out.

A. I wouldn't say that the high resistance 19 is connected between the rectifier anode and the amplifier cathode as I see it. But if the connection on the defendant's receivers, that is, the 175 and the 178 here in suit, —if that resistance is construed as being connected between the anode of the receiver or detector and the cathode of the amplifier, then in the same sense it is here.

Mr. Darby: Let me crystallize your difficulty in that respect. Referring, for example, to Plaintiff's Exhibit 2-B—is that the one your Honor has?

The Court: 3-B.

Mr. Darby: 3-B will do just as well.

Mr. Davis: I might simplify things, your Honor, by saying that we agree that in this Evans patent the resistance 19 is connected between the amplifier anode and the—

The Court: All right.

Mr. Davis:—detector anode and amplifier cathode.

Mr. Darby: That makes it unnecessary for me to ask this witness, but I would like for both the benefit of the court and Mr. Davis, to point out what our position is on that.

Your Honor will see in the original patent, in the patent in suit, in Figure 1 of the patent in suit, that the resistance 51 is connected directly to the anode of the rectifier. That, technically speaking, is met the term "connected to the anode of the rectifier."

In the defendant's set the resistance is not connected to the anode. It is connected to an inductance coil which inductance coil is connected to the anode. Now, our position is that that is not—that resistance is not connected to the anode as required by the claim. We admit that it is connected to an inductance coil which in turn is connected to the anode.

Therefore, if that term "connected to the anode" is

broad enough to include our device or read on our device it reads equally as well on the Evans patent.

Q. (By Mr. Darby): Now, I call your attention to the fact, Mr. Kelley, that in the language of the Wheeler claim it calls for a high resistance connected between the rectifier anode and the amplifier cathode. Does that make any difference as you see it?

A. Oh, not at all.

Q. All right. Then we go to the next element.

> "means including said resistance for maintaining the average potential of said anode normally negative relative to at least part of said amplifier cathode and increasingly negative with increasing amplified signal output from said amplifier."

Do you find that in the Evans patent?

A. Yes, with the following explanation, that in the drawing where he has shown the detector as a three-electrode device, the battery 16, which is the plate battery required for such a device, is interposed between the negative end or the upper end of resistance 19 and the anode of the detector tube, so that there is a constant voltage difference interposed, but the negative end of resistance 19 does become increasingly negative with increasing signal strength, and if, as instructed in the specification, a diode were employed then battery 16 would then be absent and the average potential of the anode would then maintain the—that is to say, the average potential of said anode, that is, the anode of such a two-element rectifier, would be maintained normally negative to at least a part of the control amplifier cathode.

Q. Is this an illustration of what you earlier referred to in your testimony as being meant by Mr. Wheeler in his original patent when he said that if you use—that one of the disadvantages of using a triode was that you needed an additional battery?

A. Yes. And the presence of battery 16 is an illustration of that.

Q. Does the circuit of the Evans patent include a resistance—I think we just covered that part?

A. Yes.

Q. Does the Evans patent disclose a direct current connection from the anode back to an amplifier control electrode, whereby the amplification of said amplifier is regulated automatically?

A. Yes. That direct control connection—that direct current connection is from the anode of 8, that is, the left-hand tube, the detector tube, through the battery 16, the resistance 20, battery 18, to the control grids of amplifiers 4 and 5 respectively.

Q. Now, is the coupling between the detector in Evans to the output circuit of the amplifier any more selective than an amplifier?

A. No, sir. Couplings in each and every case are through a transformer which would give the same degree of selectivity.

Mr. Darby: Now I would like to take you through the other typical claim which has been selected, claim 10 of the patent.

Q. (By Mr. Darby): Is the Evans system "a modulation carrier signal receiver having a carrier-frequency amplifier adapted to amplify modulated signals prior to detection."

A. Yes, sir.

Q. That is effected by the tubes 4 and 5?

A. 4 and 5, which precede the detector tube 8.

Q. "Which amplifier has means for tuning to a desired signal."

A. The tuning means is not shown on this drawing.

Q. They are always employed in radio receivers?

A. Well, in all carrier wave systems, tuning is abso-

lutely necessary. The tuning in the circuit here shown is before the input terminals 1 and 2 on the extreme right-hand end of the figure. That is, it occurs before then. I think I can point that out briefly in the preceding—

Q. I don't believe it is necessary.

A. It exists, anyway, and it is in the preceding Evans figure.

Q. All right. And does the Evans disclosure include "at least one amplifier vacuum tube having a cathode and a control electrode and possessing the property that its amplification decreases with increasingly negative biasing potential on said control electrode relative to the cathode."

A. Yes, sir.

Q. In each instance just state what they are by reference numerals, will you?

A. Well, in the case of the two tubes 4 and 5, that is the case.

Q. And, does the Evans patent disclose a system of automatic amplification control which includes a two-electrode rectifier coupled to the output circuit of the amplifier by means no more selective than the amplifier?

A. Having in mind the instructions in the specification, yes, sir. All of the couplings, that is the transformers, sixth, seventh and ninth, are the same character, and hence the transformer 9 would be no more selective than the preceding ones, and similarly—or, rather, not similarly, but in addition, the detector, three-element detector, shown in the drawing could be a two-element detector as taught in the specification.

Q. You have already stated in connection with claim 1 that the Evans discloses means including a high resistance connected between the rectifier anode and said amplifier cathode, and means including the said resist-

ance for maintaining the average potential of said anode normally negative relative to at least part of said amplifier cathode and increasingly negative with increasing amplified signal output from said amplifier. Now, I ask you does the Evans disclose a direct-current connection from said anode back to said amplifier control electrode for impressing thereon a negative biasing potential which varies in accordance with the average potential of said anode?

A. Yes, sir. The direct-current connection is from the plate of 2-8 through the battery 16, the resistance 20, the battery 18, and then to each of the controlled grids of tubes 4 and 5, the varying negative potential being obtained by means of the resistance 19, and that negative potential occurring in this direct current circuit at the point right close to the negative sign.

Q. Do you find in the Evans disclosure a condenser connected between said amplifier cathode and a point on said direct-current connection?

A. Yes, sir. The condenser 22 is so connected in Evans.

Q. Do you find a resistance in said direct-current connection between said point and said anode which with said condenser provides a time constant predetermined to filter out voltage fluctuations at frequencies of signal modulation?

A. ~~Yes, sir.~~ The resistance 20 performs that function in conjunction with the condenser 22.

Q. And is its effect in Evans the same as described as being, "whereby the carrier frequency amplification in said amplifier is substantially decreased automatically with increasing amplified signal output from said amplifier and the detected signal strength is automatically controlled irrespective of whether the amplifier is exactly in tune with the signal carrier?"

A. Yes, sir.

Q. You are familiar, of course, with the defendant's 175 model and 178 model here charged to be an infringement?

A. Yes, sir.

Q. I would like to direct your attention to this language, which I will state for the benefit of the court is Claim 10 of this patent, this Evans patent, and ask you to have the defendant's circuits before you or in mind in answering the question.

The Court: Use 178 to start with.

Mr. Darby: Claim 10 of this Evans patent reads as follows and I will ask you whether or not Defendant's apparatus complies therewith, or comes thereunder?

A. Will you wait just a moment until I have it? I have it here somewhere.

Mr. Darby: The circuits.

The Witness: That is that small yellow card.

Mr. Darby: Here are the circuits.

The Witness: Oh, you want to use those?

Mr. Darby: Yes.

The Witness: Very well.

Mr. Darby: Well—

Mr. Davis: Claim 10 of which patent?

Mr. Darby: Evans patent, the same patent.

Mr. Davis: The second division.

Mr. Darby: Yes.

The Court: The 323 patent.

Mr. Darby: The 323 patent, yes.

Q. (By Mr. Darby): "A gain control circuit comprising in combination, an amplifier having a grid-cathode circuit, a rectifier connected in tandem with said amplifier, a resistance element carrying rectified current from said rectifier, means for connecting said resistance element to said grid-cathode circuit of the amplifier to

control the gain of the amplifier, and means for shunting said resistance element to control the time constant of the gain control circuit."

A. I think I will have to take that a little more slowly because there are quite a few elements.

Q. All right. This Claim 10.

A. Of Evans.

Q. Claim 10 of Evans.

A. If you will allow me to take a moment.

Q. Yes, do so.

A. I will study it carefully.

The Court: All right, suppose we take a short recess.

(A recess was thereupon taken.)

Q. (By Mr. Darby): All right, Mr. Kelley, will you now answer the pending question as to whether or not Claim 10 of this Evans patent we have been considering, correctly describes and completely describes the operation of defendant's apparatus?

A. It does so precisely.

Q. Now, I call your attention to the fact that in this claim, there is referred to an amplifier having a grid-cathode circuit and a rectifier. What vacuum tube type of rectifiers which merely as rectifiers as distinguished from amplifiers, were best known in 1923, at the time this application was filed?

A. The two-electrode type.

Q. What was the longest known type of vacuum tube rectifier known at that time?

A. The two-electrode type, which was originally known as the Fleming valve.

Mr. Darby: I might state aside to your Honor, that one of the early litigations involving radio, involved the Fleming patent, and there are a number of decisions particularly in the Second Circuit, to which your attention would be called; like by Judge Mayer, of the Court

of Appeals, Judge Hough, involving the two-electrode valve rectifier.

Q. (By Mr. Darby): Now, is there anything in connection with this claim which strengthens your belief that Evans contemplated both the two-electrode type of detector, as well as the three-electrode type of detector?

Mr. Davis: I object to that, your Honor. I don't see how we can possibly get any fact from this witness that would be relevant, in that question.

The Court: Well, I take it that that is just a short way of accomplishing something that Mr. Darby might bring out. The other way I assume that ~~might~~ probably be the correct way to approach it, technically, would be for Mr. Darby to call attention to the particular part of the patent that he has ~~in mind~~.

Mr. Darby: I can do it that way.

Mr. Davis: Well, no, go ahead. I will withdraw the objection.

Q. (By Mr. Darby): Go ahead, Mr. Kelley; will you answer the question?

A. In Claim 10 of the Evans patent, he refers to the amplifier that is to be controlled in the following language, as having a grid cathode circuit, thus characterizing it as a three-electrode device; whereas the rectifier has no such limitation placed upon it. It merely recites a rectifier connected in tandem to this amplifier. And, going outside of Claim 10 and considering Claim 3, for example, which reads as follows: "In a carrier wave receiving system, two high-frequency amplifier tubes and a rectifier tube connected in tandem to an incoming line, each of said tubes comprising a grid, a cathode and an anode," and so on; including a sharp distinction between the limitations of the rectifier in Claim 3, as compared with the recitation of a rectifier in Claim 10. That is, in Claim 10, a rectifier only, and in Claim 3 it is characterized as a three-element device.

Q. Now, confining yourself to the automatic amplification control circuit of Evans and of the Wheeler reissue patent, are those circuits the same?

A. Those circuits are the same, yes, sir.

The Court: Now, wait a minute. Let me hear that question.

(Question and answer read.)

Q. If a two-electrode device was substituted for the three-electrode device as shown in the drawing of Evans, would there be any necessary change in the automatic amplification circuit, other than the omission of the battery 16 which is incident to the use of the three-electrode detector?

A. None whatever.

Mr. Davis: Well, you would have to omit the battery 17, the C battery, too. Well, never mind.

Mr. Darby: All right.

The Court: That would eliminate battery 18?

A. No.

Mr. Darby: Eliminate battery 16.

A. 16, your Honor.

Mr. Darby: As the witness has explained, to use a Wheeler device here,—in the early days it was customary in the use of batteries to just add an additional battery for the purpose required. In the broadcast receivers, you get it all from the electric light outlet.

Mr. Davis: My question—I wonder if there is any objection to my explaining what I had in mind. My question, your Honor, addressed really to Mr. Darby, perhaps improperly, was that after all, if you are going to substitute a diode for a triode, you would have to leave out the battery 17, which is the grid battery of the triode. Since you are leaving out the grid, you would have to leave out, it seems to me, the grid battery. Now, Mr. Darby said, correctly enough, that that battery is not in the control circuit.

Mr. Darby: Yes. My inquiry is directed to what changes would be necessary in the a. v. c. or the automatic amplification control circuit, and no change would be necessary. Of course, you would have to adapt the ordinary receiving circuit to the two electrodes as distinguished from the three electrodes. There is no question about that.

The Court: As I understand it, your argument is that the only change that was necessary would be a change that was necessary because of a changing from a triode to a diode, and Mr. Davis, I assume, isn't going to agree with you on that, or he may not agree with you.

Mr. Darby: No, I think Mr. Davis would agree.

The Court: As part of his argument, as I have gotten it so far, Mr. Davis.

Mr. Davis: Well, I think we are all agreed on it so far.

Q. (By Mr. Darby): Now, Mr. Kelley, will you refer to several other instances of the prior art, showing the three-electrode type of automatic volume control, but not with the same detail that you have with respect to the Evans patent. Take up first the Friis patent, which is tab No. 11 in the book of prior art.

A. The Friis patent—

The Court (Interposing): Wait a minute. If you are leaving that now, I think maybe I can ask a question here that will be helpful to me later.

As I get it, your position is that the Evans 323 patent is a flat anticipation of the alleged Wheeler invention?

Mr. Darby: Yes, sir.

The Court: If I should ultimately conclude that it is not an anticipation of the Wheeler patent, then the accused device of the defendant follows the teachings of the Evans patent rather than the teachings of the Wheeler patent?

Mr. Darby: Yes, sir. And we go a step further; that we are licensed under that patent and we are operating under it. Our position with respect to this Evans patent is that it is a complete anticipation; if not a complete anticipation, that there is no invention in Wheeler over it; and having in mind that stress has been laid to the particular type of a.v.c. circuit that Wheeler has in conjunction with the diode type of rectifier, we have established, I believe—I will contend that we have—that the identical a.v.c. circuit of Wheeler is the a.v.c. circuit of Evans, and that the mere substitution of the two-electrode device for the three-electrode device would necessitate no change in that circuit, other than the elimination of the battery which is incident to the use of the three-element device, so that there was no invention involved.

That crystallizes our position with respect to it.

The Court: Well, as I understand the picture now, the reissue patent resulted in a narrowing of the claims of the original Wheeler patent. That is, it is your claim —it is the plaintiff's position that the claims in the reissue are narrowed, narrower than the claims in the original patent?

Mr. Darby: That is right.

The Court: Well, the point I think I had in mind, Mr. Darby, was this: That if you assume that by narrowing these claims and limiting Wheeler's claims to his patent into a narrower field, make the Wheeler reissue a narrower patent, then you are outside of the scope of that patent, because you follow the teaching of the Evans patent rather than the Wheeler reissue.

Mr. Darby: That is correct. And in addition to that, there is the issue of validity as well, as crystallized.

The Court: Yes, but I understand you don't concede the validity of the Wheeler reissue.

Mr. Darby: They say they have narrowed their claims,

and I say, "To what?" And we develop by the plaintiff's prima facie case just to what they have narrowed it. They have narrowed it to a diode and a particular a.v.c. circuit with that diode. I say there is a complete anticipation, because it is that identical circuit and teaching that they used a diode, and in addition to that, you would have the—there is always the point of even though narrowed down to what they say their claims are narrowed to, whether or not that amounted to an invention.

The Court: Yes. I understand.

Mr. Davis: I don't think it is fair to let the thing stand the way it does now, because it is not Mr. Darby's contention that defendant make use of the circuits of Evans rather than the circuits of Wheeler.

Mr. Darby: Oh, yes, it is, Mr. Davis. Yes, it is. That is it precisely.

Mr. Davis: It can't be, there is no question about it, and the point is, your Honor, this. I think I must explain. Counsel conveyed that impression to the Court by reading a claim of the Evans patent, which claim, by the way, was drawn long after the Wheeler invention had become known, by reading that claim upon the defendant's set.

Well, he could read that claim on the Wheeler set. In other words, that claim is a broad definition which embraces both Wheeler's circuit and Evans' circuit, but Mr. Darby, in spite of what he says, does not contend that the defendant uses the triode electrode, triode rectifier with its batteries, which are shown in Evans, but must admit that he uses a diode rectifier without those batteries as shown in Wheeler.

Mr. Darby: So that Mr. Davis can squarely meet my contention, I will state it. It is this: That if, as Mr. Kelley has pointed out—that so far as the a.v.c. circuit

is concerned, the defendant uses the a.v.c. circuit of the Evans patent, and that if the Wheeler patent with which Evans differs to the same extent that that defendant's circuit differs, if the Wheeler patent claims are construed to cover the defendant's set, then they are completely anticipated by the Evans patent, so we either don't infringe or their claim is invalid.

We contend that we do use the two-electrode rectifier as taught by the Evans patent. Now, there is the issue of fact. You will contend that it doesn't teach it. I contend it does, and I have advanced the reasons for it.

Mr. Davis: But the issue of fact is not on what the defendant uses but on who taught it.

Mr. Darby: That is right:

Mr. Davis: That is the point I want to bring out.

Mr. Darby: I agree with you. I agree with that. And I also contend on the evidence that is thus far advanced as to this patent that there is no patentable invention in using a two-electrode device as distinguished from a three-electrode device.

Mr. Davis: That is the issue, isn't it?

The Court: I am sure I understand you all right.

Q. (By Mr. Darby): All right. Now, will you very briefly discuss the Friis patent.

A. The patent to Friis is No. 1675848. The very first paragraph describes what it is all about.

> "This invention relates to radio receiving systems and more particularly to methods of and means for controlling the intensity of received signals at a uniform level."

That means automatic amplification control in the same sense that it is used in the Wheeler patent.

Figure 1 shows the circuit, the entire circuit of the system, in which the radio waves which are picked up by the loop of wire 1, which is at the extreme left-hand

position, and from there successfully amplified in the tubes 3, the first one on the left, and 4, and in tube 5, this being a super-heterodyne receiver, there is a first detection which results in converting the modulated carrier wave to a lower intermediate frequency which is still amplified and selected by the apparatus which is not shown in detail, but which is indicated in boxes 6 and 7. 6 is a filter which is for tuning. 7 is an amplifier detector which amplifies and performs a second detection of the modulated carrier signal.

Part of this goes directly to another amplifier, the details of which are not shown, 8, but which is labelled L. F. amplifier, meaning low frequency amplifier. In other words, frequencies of the voice or speech or music, and eventually to the loudspeaker indicated by the figure 9.

The output—that is to say, the circuit branches after the detector amplifier detector 7, proceeding downward by the two parallel lines through a condenser 13 and a coil 14 to the input of another amplifier which is marked 15.

The carrier wave is then amplified detected in the tube 16, the output of which consists of a current flowing through the resistance 18, this being a direct current producing the negative voltage for the purposes of amplification control. That negative voltage is developed at the upper end of the resistance 18 and is supplied to the control grid of the amplifier tube marked 4 in the following way:

Beginning with the upper end of resistance 18, going up that vertical line to the first junction point, and then proceeding horizontally to the right and around the bend vertically upwards, and taking the bend to the left a short distance horizontally to that point between two coils; from that point going up and around to the grid

of the amplifier tube 4; thus, the negative bias of the amplifier 4 is automatically controlled by the variations in the direct current flowing through the resistance 18, which, in turn, depends upon the strength of the incoming signal, and thus effecting automatic amplification control.

There are two other figures on the page, and I refer briefly to Figure 3.

Figure 3 shows a curve of the resultant of the operation showing that when the impressed signal increases above a certain point, the output, that is the volume, will not increase appreciably even though the signal increases considerably above that point.

Q. Does that curve—

A. This curve—

Q. Pardon me, go ahead.

A. This curve indicates the same thing that is intended to be indicated in the curve shown in Figure 2 of the Wheeler patent in suit. That is the curve which is indicated by the number 103. In the specification is a very detailed and elaborate description of how the system worked. I don't know to what extent you wish me to—

Q. (Interposing): Only call attention to any particular passages that in your judgment are of sufficient importance to warrant them.

The Court: When you do this, Mr. Kelley, can you point out any differences between the Friis circuit and the Wheeler circuit of the patent in suit?

A. With regard to the a.v.c. circuit only, they are the same.

The Court: That is what I meant.

A. And, there are extra amplifier tubes included, but that is not a part of the specific a.v.c. circuit.

Q. All right. Then, will you take up the Affel patent, No. 1574780?

A. This is another patent describing automatic amplification control, and in Affel's words on page 1, beginning at line 18, it is described generally as follows:

> "Another object of the invention is to control the amplification of an amplifying device directly by the amplitude of the input current supplied by the device."

That is automatic amplification control. And, means of control is by the agency of the negative grid bias of the amplifier tube as he points out.

Also on page 1, beginning at line 60, and here he is referring to Figure 1, which is a very simple diagram, and he says:

> "The amplification of the tube AT, [that is the upper one] may be varied by variably adjusting the static grid potential of the tube."

That is the same as saying the negative grid bias of that tube.

> "In order to adjust the static potential of the grid, and hence the amplification of the tube in accordance with the amplitude of the input current, a rectifying tube RT is provided."

That is, RT is the rectifier which generates the current which is converted into the voltage for controlling the negative grid bias automatically in accordance with the strength of the received signal.

> "The rectifying tube RT is so arranged that a portion of the input energy applied by the transformer 1 may be applied to the grid circuit of the rectifying tube to a transformer 3. The output circuit of the rectifying tube RT is connected across the terminals of a resistance 4 in the grid circuit of the amplifier AT, so that the rectified

> potential will determine the potential of the grid of the amplifier AT. As the rectified potential will be a function of the amplitude of the input energy applied to the amplifier AT, the amplification of the amplifier AT may thus be made to depend upon the amplitude of the input energy."

Thus describing rather completely the functioning of the circuit as an automatic amplification control circuit.

Q. Now, with respect to the Evans and Friis patents, is it the fact that the voltage for amplification control is obtained after the carrier signal has passed through the amplifier?

A. Yes, sir, in both cases.

Q. In this Affel patent, however, the voltage for amplification control is obtained before the carrier current goes through the amplifier; is that correct?

A. That is right.

Q. In so far as amplification control is concerned, does it make any difference whether the voltage for automatic control is obtained before or after it goes through the amplifier?

A. In the end result there is no substantial difference, and that is indicated in the curve shown in Figure 5 of this Affel patent which represents the end result. That is, it shows the control. And this curve, likewise, is intended to represent a result precisely the same as the curve, I think it is of Figure 2 in the Wheeler patent in suit.

Q. Now, how does the automatic amplification control circuit alone in this Affel disclosure compare with the automatic amplification control of the Wheeler patent?

A. Well, in this patent there is a little simplification of the automatic control circuit used by Wheeler in that the resistance 4 in Figure 1 of Affel is included in series

in the grid circuit of the amplifier AT, and thus applies the negative grid voltage directly in series in that circuit. The condenser which is connected across and parallel with 4, just below 4, performs the function of preventing the high frequency part of the rectifier output from getting into that grid circuit.

In other words, having put the resistance 4 in series with the grid circuit, it isn't necessary to add another combination of resistance to capacity for timing purposes. In other words, the resistance 4 and the capacity unnumbered just below it, performs that function also.

Q. In the defendant's accused structure—you have a set of the prints there, haven't you?

The Court: Do you want to use mine?

Mr. Davis: Here is a copy (handing copy to Mr. Darby).

Q. In the respect of this time constant feature, is the Detrola receiver more similar to the Wheeler patent or is it more similar to the Affel patent in this respect?

A. (No response).

Q. Or is it different from both?

A. Well, that is what I was going to say. It is different from both.

Q. All right. Now, thus far you have been considering only automatic volume control systems employing, in so far as the drawings are concerned, at least, three-electrode amplifying detecting devices. Will you now refer to the use, as shown in the prior art, of two-electrode devices in connection with automatic volume control, where they are depicted as two-electrode devices, taking up first the Slepian patent.

A. The Slepian patent is No. 1455768. It is a wireless receiving system; in modern terminology, a radio receiver. I think that I can characterize the disclosure best by referring to the specification, to page 1, beginning at line 20:

"More specifically one object of my invention is to provide a receiving system which admits of an extremely high amplification of received signal impulses."

In addition to that—and I will explain it afterwards, just state it generally first—what Slepian is describing here, what he intends to do, is to utilize a single three-electrode amplifier for radio receiving purposes to obtain an extremely large amplification which is beyond the ordinary use of the tube. And he does that by means of the circuit which is shown in Figure 1. The three-electrode amplifier tube—it operates both as an amplifier and a detector, incidentally—is the upper one enclosed in the circles numbered 1. The radio energy comes in on the antenna, which is indicated by the number 23 in the upper left-hand corner of the figure, and is passed from the antenna circuit through the transformer 25-15 and thence to the—or, rather, from the transformer, from 25 to 7, and thence to the grid filament circuit of the amplifier tube, the three-electrode tube. This amplifier is of the so-called feed-back type, in which the output circuit is arranged so that it is able to supply the input circuit with additional energy.

That output circuit goes from the plate electrode tube of the three-electrode amplifier, following the vertical line up, then horizontally to the left, and then downward through the combination of the coil and condenser 15 and 14; then horizontally along the bottom line through the battery 12, and thence through the telephone head-set, indicating a means for reproducing the sound, and eventually to the filament or cathode circuit. That is, the output circuit of the amplifier.

Also coupled to that output circuit is another circuit. Coupling between the output circuit and this other circuit which I am about to describe is from the coil 15

to the coil 16. The coil 16 is in the circuit in series with a two-electrode rectifier No. 18—that is the instrumentality enclosed in the lower circle—having a cathode 21 and an anode 19. The circuit which includes this two-electrode rectifier, beginning at the coil 16, going down and then horizontally to the right and upward to the anode 19, thence through the space between the two elements to the cathode 21, thence upward to the horizontal line at about the center of the figure and then to the left; and here is encountered a high resistance 9 and a condenser 8 in parallel with each other, and in series with respect to the circuit I am now tracing, so that after passing through the combination of the condenser 8 and resistance 9, the series continues to the left, jogs down and then to the left to the coil 16, thus completing that series circuit.

The coupling from the output circuit of the amplifier to the circuit of the rectifier is indicated in the specification beginning on page 1, line 109. I have to read a few lines more than refers merely to that coupling, but I shall explain that afterwards.

> "An auxiliary grid-biasing means is provided for increasing the negative charges on the grid condenser 8 to values greater than the peak-value of the alternating current potential in accordance with the varying"—

Q. Alternating grid potential.

> A. "—alternating-grid potential in accordance with the varying intensity of the disturbing impulses tending to unbalance the feed-back system, and comprises a coupling coil 16 inductively coupled to the tuned circuit 13 and deriving alternating voltage therefrom and translating means 17 for rectifying said voltage, all of which are serially

> included in a circuit connected in shunt relation to the grid condenser 8."

That is, the tuned circuit 13 which is in the output circuit of the amplifier tube is inductively coupled, that is, coupled to the rectifier circuit by means of coil 16.

Q. Are you through?

A. I believe so, yes, sir.

Q. But, now, as I understand the disclosure of this patent, the grid of the amplifier is controlled—is the grid of an amplifier controlled by the voltage developed in the resistance as a result of the rectifying action of a two-electrode tube?

A. Yes, sir.

Q. As I understand the disclosure of the patent, Slepian controls the grid electrode of the amplifier for the purpose of obtaining at all times maximum amplification from the tube; is that right?

A. Yes, sir. He says "extremely high amplification."

Q. Whereas the Wheeler patent employs automatic control on the grid of the amplifier for the purpose of maintaining a level volume of sound; is that right?

A. That is correct, sir.

Q. So that the ultimate results in the two devices differ in that respect, at least?

A. Yes, sir.

Q. However, is there any difference in the automatic control of the grid of the amplifier between Slepian on the one hand and the Wheeler patent on the other?

A. No, sir. In both cases the control is effected by the change of the negative grid bias.

Q. And do they both use the same instrumentalities for that purpose?

A. Yes, sir.

Q. And do those instrumentalities operate in the same way for that purpose?

A. Yes, sir.

Q. Now, I would like to carry you through the Claim 1 of the Wheeler patent as typical with respect to the disclosure of the Slepian patent.

Does this patent show a signal receiver having a carrier frequency amplifier which includes at least one vacuum tube having a cathode and a control electrode?

A. ~~Yes,~~ sir. That vacuum tube is tube No. 1, the upper one.

Q. Does it employ a two-electrode rectifier coupled to the output circuit of the amplifier?

A. Yes, sir, as I have described, through the tuned circuit 13 which is in the output of the amplifier to the coil 16 which is in series with the rectifier.

Q. Is there employed a high resistance connected between the rectifier anode and the amplifier cathode?

A. Well, I wouldn't say that it is connected in that way, but, as I answered previously, if this expression in claim 1 is construed to mean the same thing that the defendant does, then under those conditions I say yes.

Q. In other words, there is connected between the high resistance in Slepian, the high resistance 9 and the anode 19 of the two-electrode rectifier 18, the inductance coil 16?

A. That is correct, sir.

Q. And in defendant's apparatus there is likewise an inductance coil between the high resistance and the anode of the rectifier?

A. That is right, sir.

Q. Is there in the Slepian disclosure means including said resistance for maintaining the average potential of said anode normally negative relative to at least part of said amplifier cathode?

A. Yes, sir. The resistance 9, which is included serially in the rectifier circuit, is connected on one side to the cathode of the amplifier, the cathode being numbered 4,

and at the other end where the negative potential is developed, and must occur whenever any current or even when no current flows if the cathode of the rectifier is energized. In other words, yes, sir.

Q. And is it increasingly negative with increasing amplified signal output from the amplifier?

A. That is necessarily so.

Q. And is there a direct current connection from the anode back to said amplifier control electrode whereby the amplification of the amplifier is regulated automatically?

A. Yes, sir. That connection is from the anode 19 through the coil 16, the coil 7, and thence up and around to the control grid 3 of the amplifier tube.

Q. Was it customary to use, or was it proposed to use, or was it known to use automatic amplification control for transmitting equipment as well as receiving equipment?

A. Yes, sir.

Q. Was it just as desirable in transmitting equipment as in receiving equipment?

A. Yes, sir.

Q. Will you refer to the Heising patent?

A. The Heising patent is No. 1687245. This is a modulated carrier wave amplifying system for purposes of transmitting. That is, what comes out of this arrangement as the ultimate product is applied to a radio antenna for purposes of broadcasting, or whatever it may be. But, at any rate, we are here dealing with large amounts of energy. In other words, the modulated carrier wave will be quite large, particularly in the portion of the circuit which is nearest to the right. I am referring to Figure 1 particularly.

In the specification Heising says that, at page 1, line 76:

"It is an object of this invention to amplify zero carrier waves by vacuum tube amplifier systems working at high efficiency. In this specification, the expression 'high efficiency' is used to describe the condition of operation in which the ratio of the energy of the desired wave form produced in the output circuit to the total energy supplied to the amplifier system is high."

That is the object which Heising features, and that object is similarly touched upon by Wheeler in the patent in suit, along with other objects.

On page 1 of the Wheeler patent, first column, line 55, where it is stated:

"A still further advantage is the saving in plate current which is automatically effected during the reception of powerful signals, for the reason that this invention incidentally provides means for reducing the plate current of one or more amplifying tubes as the signal strength increases."

Heising intends to do that, and he does so by means of a two-electrode, a diode rectifier, which in Figure 1, about the middle of the figure, is indicated by the number 11.

The diode works with a high resistance 12, the high resistance 12 being connected in series with the diode tube that I have referred to.

On page 3, beginning at line 22, for instance, he says:

"A rectifier 11, preferably in the form of an evacuated tube having a cathode and an anode is connected across between the grids and the filaments of the tubes 5 so that incoming waves will be partially rectified in a manner tending to make the grid more negative. The greater the amplitude

> of the waves, the more negative the grids will become."

He here describes the rectifier as a diode or two-element rectifier, and also that the manner of control which is exercised on the control amplifier is by making automatically the grid more negative in the presence of larger waves.

The resistance across which the controlled voltage is developed, that is No. 12, is referred to on page 3, line 39, as a "high resistance 12".

Then, a little more detailed description of the operation is given on page 3, line 62:

> "The negative potential of the grid thus rises and falls in such a manner that when large waves are amplified, the grid is at such a high negative potential as to create an efficient operating condition. When small waves are amplified, only a small amount of power is needed, hence, the average efficiency over a complete low frequency cycle remains fairly high."

And, he has previously explained that the source of this power is from the plate battery, that is the generator of the plate voltage, and it is his object to economize by this amplification control on the consumption of energy from the source of plate voltage.

Q. Now, have you pointed out specifically the amplification control circuit by which this is effected?

A. I don't believe I went into sufficient detail to make it clear, so I will do so now.

The signal comes and is amplified in the direction from left to right before it reaches the diode 11. The diode 11 is connected in such a way in this circuit that the signal is caused to flow through it in series, that is through the rectifier, two-electrode rectifier 11 in series, and also

in series with the high resistance 12, and it is the rectified current that is generated flowing through the resistance 12, and causes the upper end or where the connection is made from that little short line that goes to a dot on Figure 12, to make that more negative when the signals are larger and less negative when they are smaller; that connection being applied directly to the grids of the three amplifier tubes 5 which are operated as a single-stage of amplification.

That is how the control is effected.

Q. And, what is the function of the condenser right to the left of the anode resistance 13?

A. The function of that condenser is two-fold. It is to block out the voltage of the source of plate voltage numbered 9, and at the same time provide coupling means for the signal voltage to be applied to the rectifier, the diode.

Q. Confining your consideration now to the automatic amplification control, how does the circuit of Heising for automatic amplification control compare with the circuit of the Wheeler reissue patent for automatic amplification control?

A. It is the same, except that there is no time constant capacity included.

Q. And, does Heising employ a diode or two-electrode rectifier in his automatic amplification control for the same purpose and in the same manner as it is employed in the Wheeler reissue?

A. In a general way, yes, sir.

Q. That is they are both for rectifying purposes?

A. Yes.

Q. And do they both develop by means of—I don't know whether I am stating it correctly—do they both serve to develop a voltage through means of a resistance which is applicable to the grid electrode of the controlled amplifier?

A. Yes, sir.

Q. Now, I direct your attention to Claim 4 of this Heising patent, and ask you if that correctly describes the apparatus or operation of the defendant's receivers both model 175 and model 178. It reads as follows:

> "The method of repeating a high frequency wave of variable amplitude by means of a space discharge device which comprises rectifying a portion of the high frequency wave energy by means of a device other than the space discharge device and applying to the space discharge device a potential difference resulting from the rectification to control the repetition of the high frequency waves by the space discharge device."

A. Yes, sir.

Q. Will you now turn to the Schelleng patent and very briefly describe the automatic amplification control there disclosed, if it is so disclosed?

A. Have you given the number?

Q. No.

A. The number of the Schelleng patent to which I am referring is 1836556. The circuit here disclosed is illustrated likewise as a transmitting circuit. The amplification control is brought about as follows: First of all I will just indicate briefly where the energy originates and where it goes to.

First of all, on the extreme left-hand end there is a box with a number 1, and in that box is supposed to take place the creation of a modulated carrier wave signal. Everything from there on going to the right is connected with that carrier wave signal. Taking the upper part of the figure and going from the transformer 2 towards the right, first the carrier wave signal is amplified through the tube 3 and other tubes of a similar

nature in the box labelled "power amplifiers", and so on out to the right and eventually it gets on to the antenna circuit which is on the extreme right-hand edge of the drawing. That is the circuit, generally speaking, without automatic amplification control. The part which provides amplification control is in the lower part of the figure. The energy, that is, the carrier wave signal which is utilized for the purpose of automatic amplification control is picked up by the wires 22 and 23 near the right-hand part of the drawing and there fed into two diodes in succession, the first diode or two-electrode tube being No. 9, the second diode to the left being No. 19. The method of amplification control here is a two-stage affair as indicated by the two diodes. The first diode No. 9 generates in the resistance 18 the control negative voltage, but it is not applied directly to the grid of the control amplifier.

The control is effected by combining this voltage with the battery voltage 20 in connection with the diode No. 19 in such a way that when the signal increases there will be an increase of negative potential at the lower end of resistance 18, which results in a shunting effect on the signal which is going from transformer 2 into the amplifier tube 3, and this shunting or taking away of the energy that might otherwise go into the amplifier results in a control of the amplification.

Q. In this Schelleng disclosure, is there employed a diode or two-electrode device for the purpose of generating a voltage potential in a circuit which controls the grid electrode of an amplifier?

A. Yes, sir.

Q. And is that potential developed by means of a resistance?

A. Yes, sir.

Q. A high resistance?

A. The resistance 18.

Q. Now, one of the claims of the Wheeler patent, reissue patent in suit, makes reference to the utilization—or to the manner of coupling which is stated to be "no more selective than the amplifier". Will you please state what is the significance of that type of coupling and how it is effected in the Wheeler patent?

A. Well, as I understand what is meant by that in the Wheeler patent, it is this: That whatever coupling circuits may be used in connection with control amplifier as to their ability to transmit a range of frequencies, then that same range of frequencies, or, at least, that same range of frequencies shall be transmitted in a coupling circuit which leads to the rectifier.

Q. And what instrumentalities does the Wheeler patent disclose for accomplishing that?

A. It shows—

Q. Identify them by number?

A. He shows it in Figure 1. The control amplifier, of course, is the first one, beginning at the left-hand side, and the coupling to that amplifier is from the antenna 5 through the coils 6 and 7, the latter of which is tuned by the condenser 8. In other words, it is a tuned coupling here.

Q. Now, is that—

A. That is tuned—I just wanted to make one more statement, that it is tuned at the radio-frequency or the wave length of the signal which it is desired to receive. Similarly, the coupling from the output of this whole amplifier section which goes up to the third tube is through the primary winding 30 and secondary winding 31 of a radio-frequency transformer which likewise is tuned by a condenser, adjustable condenser 32. That is, the two coupling circuits are tuned coupling circuits, both tuned to the same frequency.

Q. And what type of coupling is employed by Wheeler in Figure 1 of this patent between the rectifier and the first stage of the audio-frequency amplification?

A. That is the so-called capacity resistance coupling.

Q. Was that an old type of coupling employed in the art prior to Wheeler?

A. Yes. There were a number of alternative couplings that were used to couple amplifier tubes, and this was a very common one.

Q. Now, will you refer to the Arnold patent—

The Court (Interposing): Mr. Darby, may we interrupt here? You don't need to take this.

(Discussion off the record.)

The Court: Suppose we quit now. When you come back, make it Tuesday morning at 9:30.

(Whereupon an adjournment was taken until Tuesday, October 31, 1939, at 9:30 o'clock A. M.)

Detroit, Michigan,
Tuesday October 31, 1939,
9:30 o'clock A.M.

Court met pursuant to adjournment.

The Court: All right, Mr. Darby.

Mr. Darby: Mr. Kelley.

LEO A. KELLEY, a witness, called on behalf of the Defendant, having been previously duly sworn, resumed the stand, and testified further as follows:

Direct Examination (Continued)

By Mr. Darby:

Q. Mr. Kelley, claim 4 of the Wheeler re-issue patent

recites that in the connection from the rectifier to the modulation frequency amplifier, there is included a condenser in series for preventing the uni-directional component from being impressed upon the input of said modulation frequency amplifier. Will you please point out those instrumentalities in Figure 1 of the Wheeler re-issue patent, giving them their identification symbols, and also state what the functions of those instrumentalities are?

A. The condenser referred to in that claim is shown in Figure 1 as condenser number 40. It is located between the fourth and fifth amplifier tubes reading from left to right. The tube 39, which is the next to the last tube, is the modulation frequency amplifier.

Q. What is it usually called?

A. It is usually called the audio-frequency amplifier and the condenser 40 shown in this figure is located in such a manner as to prevent any direct current potential on the left side of 40 from being impressed upon the grid 43 of the modulation frequency amplifier 39.

Q. Is this method of coupling an audio-frequency amplifier or coupling any vacuum tube with another vacuum tube, preceding it in a series, well-known in the art?

A. Yes. I have mentioned it previously in my testimony where I referred to it as capacity resistant type of coupling. The capacity is used with other forms of coupling as well.

Q. Can you refer to an instance of the prior art where that type of coupling is shown?

A. Yes, and I refer to the Arnold patent, which is number 1504537. Referring to the figure of the drawing of this patent and particularly to the condenser 26 which is located between the second and third amplifier tubes, reading from left to right, the condenser 26 performs the same function in this circuit of Arnold as the con-

denser 40 performs in the circuit of Figure 1 of the Wheeler re-issue patent.

Mr. Davis: Wait a minute. We the plaintiff, do not dispute this fact, as has already been testified to by the witness, namely, that the resistance condenser coupling is old, and that it is shown in the Arnold patent.

Mr. Darby: Very well.

Mr. Adams: Our proposed finding 31-A states that.

Mr. Darby: I know, but my difficulty is our findings were prepared before evidence to support them, so that with that concession it won't be necessary to go any further into it than to ask you to refer to the original Wheeler patent with respect to this type of coupling?

A. Well, very briefly I would like to add just one more thing in respect to the Arnold patent, and then go to the Wheeler patent.

Q. All right, please yourself.

Mr. Davis: Be sure you don't talk yourself out of the admission, Mr. Kelley.

Mr. Darby: We will run that risk.

A. I am sure I won't do that, Mr. Davis. Referring again to the figure of the drawing of the Arnold patent, and the type of coupling which is used in the next two following—between the next two following amplifier tubes, it is seen—there is seen there to be a transformer which has primary and secondary windings 32 and 36. That is all that I wanted to point out in addition in the Arnold patent.

Q. Are these two types of couplings considered to be alternative or optional in the art?

A. Yes, and their presence, one succeeding the other in the Arnold circuit illustrates that.

Going now to the Wheeler original patent number 1879863 and referring particularly to Figures 4 and 5.

In Figure 5 there seems to be a fragmentary drawing,

that is, it just shows that portion of the circuit which is considered pertinent for that purpose. And there is there shown a condenser 117 located between the two tubes that are shown, tube number 94 and 105. 105 is a modulation or audio-frequency amplifier, and 117 is the condenser, performs the same function as condenser 40 in the re-issue patent in suit.

In the text at page 5, beginning at line 122, and going to line 129, the circuit of Figure 5 is described as being alternative to the portion of the circuit of Figure 4 which is enclosed in dotted rectangles—in a dotted rectangle.

The circuit of Figure 4, the short section of the circuit, contains the transformer 99, which is the circuit of Figure 5, said in the specification to be an alternative way of coupling.

Q. Now, I would like to direct your attention to the subject of the visual indicator to which reference was made in plaintiff's prima facie case. You have operated radio receiving sets in your experience, Mr. Kelley?

A. Yes, for a great many years, sir.

Q. And you are familiar with what is necessary to be done manually and electrically to obtain resonance?

A. Yes, sir.

Q. In receiving radio signals by an ordinary radio broadcast receiver, after you have attained the necessary volume to make the signal that you desire to receive audible to your ear, how do you bring the receiver in tune or in resonance, and what tells you when you have received resonance?

A. Well, having approximately tuned so as to make the volume of the signal, the signal will still sound harsh or unpleasant unless it is precisely tuned. The precise tuning consists in clearing out that mushing extra hardness in what is heard, as the real final tuning is not

so much a volume change as it is a change in clarity, and that is judged by the ear.

Q. Now, my question is what is the important feature, assuming that you have sufficient volume to make—have sufficient volume to make the signal audible, plainly audible, is resonance affected by any alteration in volume, or is it affected by the clarity of the signal received?

A. It is affected almost entirely by the clarity of the signal by this final adjustment.

Q. Is it a fact that for a great many years ordinary home receivers employed no type of visible tuning means?

A. Oh, yes.

Q. And throughout all those years, was it the clarity that was utilized—

Mr. Davis: I object to that.

Mr. Darby: Leading?

Mr. Davis: Yes.

Mr. Darby: All right.

Q. Throughout all those years, what was the physical phenomenon that determined accurately tuning and resonance?

A. Well, just as I have previously described, that is the final tuning is always one of clearing up the unpleasantness caused by the mis-tuning, that is, a clarifying of the sound.

Q. As a matter of fact, is visible tuning universally practiced today?

A. No. A very large percentage of all of the radio receivers in use today do not use visual tuning of any kind.

An illustration of that is the two accused sets. Of them only one has visual tuning. The other has not.

Q. Was visual tuning known in the art prior to Wheeler?

A. Yes, and it was applied to radio receiving systems.

Q. Now, this is a minor point in the case, but will you just refer to two instances of visible tuning in broadcast receivers, radio receivers?

A. Well, first of all I would like to refer to Perry—

The Court: The thought just occurred to me here, these two systems of tuning a radio are not exclusive, that is, in other words, the mere fact you had means for visibly tuning a radio wouldn't be any evidence that you used it?

A. Not in itself, your Honor, but it would be an added convenience which is largely the reason for having it. If you did use it, it would be convenient to do so, or you could tune it without even looking at it.

The Court: What I meant to say, the fact that you have then visible means of determining whether the radio is in tune in no way affects the means of determining by ear that it is in tune?

A. Not at all, your Honor. You could do it either way.

Q. All right. Will you please refer to the Perry patent number 1536130, and point out the visible tuning means there shown?

A. The visual tuning means is shown in the figure of the drawing at the extreme right-hand side and is indicated by the numeral 20. It is a circle with an arrow inside of the circle.

Q. What does that designate?

A. That arrow inside of the circle is a symbol for the needle of the meter.

Q. In other words, that is an ammeter or a volt meter?

A. Probably a milliameter. The circuit is tuned by the adjustable condenser which is shown in the antenna circuit on the extreme left-hand side, that is, there is

below the letters "T.R." which has a coil going directly down, and then the condenser with an arrow through it. That condenser is the means for tuning and the meter 20 that I referred to is the visual means for observing when resonance is attained.

Q. And so described by the patent?

A. Yes, and there is a particular reference, just a short reference in the specification at page 4, beginning at line 41, which reads as follows:

> "To aid in properly tuning the variable condenser in the circuit of the antenna T.R., an ammeter 20 is shown connected in circuit with the operating winding of the receiving relay R. A change in the adjustment of the tuning condenser will vary the frequency of the beat note assuming that the distant station is emitting a constant frequency. The maximum ammeter reading will indicate the beat note best transmitted through the band filter and the optimum setting of the variable condenser."

Q. Now, will you refer to the other instance that you selected, namely, the publication, "The Wireless World and Radio Review", of June 16, 1923?

A. This article describes a radio receiver. On the second page, that is, the second page of the article, that is, page 335, beginning at the top of the second column:

> "An unusual feature is the fact that both the aerial and closed circuits may be visually tuned. This is done by means of a small milliammeter mounted in the high tension unit. The accumulating negative potential on the grid of any valve is clearly recorded by the reduction in anode current shown on the milliammeter. In addition, the maximum degree of resonance in all the tuned circuit can be 'seen' without listening for signals."

Then dropping down to the next following paragraph:

> "The author finds that much sharper tuning can be obtained in this way than by relying on the ear. Further, tuning can be effected immediately the carrier wave is located, and before signals are actually transmitted."

And on page 338, which is the next to the last page of the article, in the second column, beginning about in the middle:

> "In the centre of the panel is mounted a 0-5 milliammeter, and below this is a change-over switch connecting it in series with the plate circuit of either of the first three valves or the plate circuit of either of the last four valves."

That is the end of the quotation.

Q. Now, will a visible device, such as a meter for accurate tuning, when properly connected in the circuit for that purpose, perform its function of visually indicating resonance regardless of whether or not there is an automatic amplification control system coupled with the receiver?

A. Yes, certainly.

Q. Will the automatic amplification control arrangement perform its function regardless of whether or not there is a visible tuning device?

A. Yes, sir.

Q. Now, Mr. Kelley, I would like to direct your attention to the subject of infringement, and ask you to first refer to the re-issue patent, and, for the time being, I am interested principally in the differences between the disclosures of the Wheeler re-issue patent and the circuits employed in the defendant's receivers as depicted in Plaintiff's Exhibits 2-B and 3-B.

Will you first refer to the specifications of the Wheeler re-issue patent, page 2, line 46, first column, and point out what is there described, where it is found in the Wheeler circuit, and what its function is, and state whether or not the defendant's receivers employ any similar arrangement?

A. You wish me to read that from the patent?

Q. Yes, please.

A. Very well:

> "The output circuit of the rectifier 33 includes what may be termed a 'rejector' circuit for stopping radio-frequency currents which have passed through the rectifier, and consists of a network including a resistance 34 and a by-pass condenser 37 connected between the anode 35 and the filament 38 of the rectifier."

Such a circuit is not used in either of the defendant's sets.

Q. Now, where is that rejector circuit found in the Wheeler drawing, Figure 1?

A. By referring to Figure 1, that rejector circuit is found just to the right of the fourth tube from the left.

Q. That is the detector tube?

A. Yes, sir, the detector tube. The resistance is number 34 and the condenser is number 37. And the necessity for using that so-called rejector circuit is because of the specific way in which the detector circuit is connected. In other words, the resistance 51 being shown connected from the anode to the cathode, and the condenser tube being connected in series with the detector. The effect of such a connection is this:

That, incoming signals which are picked up by the coil 31—the signal to be considered as travelling in a left to right direction through these various tubes, and

coupled circuits—is picked up by coil 31 and is applied across the diode, that is, the triode connected as a diode, 33, with the condenser 2 in series in that connection. The resistance 51 has developed in it the rectified current which is of a pulsating nature.

The point 52, from which the direct connection to the control grids of the amplifiers that are controlled is taken off, by this arrangement, is exposed to the high-frequency or the carrier frequency oscillations, because of the location of the condenser 2 and the location of the resistance 51, and since the point 52 is thus exposed to the carrier or high-frequencies, something must be done in order to take those high-frequencies out of the direct current connection, and that is done in Figure 1 of the Wheeler re-issue patent by means of the resistance 34 and the condenser 37. That is the reason it is called a rejector circuit.

Q. Is the utilization of this rejector circuit absolutely essential with the type of automatic amplification control circuit employed by Wheeler?

A. Yes, sir.

Q. Does either of the defendant's receivers employ either the condenser 37 or the resistance 51, or the rejector circuit or any equivalent of them?

A. I think you meant condenser 37 and resistance 34.

Q. Yes, I did.

A. No, they do not, and that comes about by virtue of the difference in the connection of the elements in the detector circuit.

Q. In other words, let me ask you this question: Do either of the defendant's circuits, defendant's receivers, employ the same automatic amplification control circuit of the Wheeler patent?

A. No, sir.

Q. Do the defendant's receivers by the particular auto-

matic amplification control arrangement employed by them, completely dispense with the use of condenser 68 and resistance—

Mr. Davis: I object.

Q. Wait a minute. Wrong figure. Condenser 37 and resistance 34, those physical instrumentalities?

Mr. Davis: I object. I think Mr. Darby ought not to ask those argumentative questions. Let us get at the facts.

Mr. Darby: That is the fact. I am pressing my question. I think it is quite proper.

Mr. Davis: I object to the form of the question.

The Court: Let us hear the question.

(The question was read by the reporter.)

The Court: The objection is overruled.

A. How?

The Court: You may answer.

A. They do so dispense with the resistance 34 and the condenser 37.

Q. Now, will you turn to the re-issue patent, page 3, line 19, column 1, and quote the langauge there employed and point out its significance with respect to the Wheeler arrangement?

A. It is stated there:

> "The level at which the volume is maintained uniform is determined by adjustment of rheostat 49 which controls the heating current in the filament 42 of the first audio-frequency amplifying tube 39."

Referring to Figure 1 and referring to the next to the last tube the circuit associated with the next to the last tube number 39, immediately below the circle which encloses the elements of that tube is the rheostat 49, which is simply an adjustable resistance for controlling

the amount of current that will flow through the filament of that tube number 42.

The passage which I read points out that this is the means for adjusting manually for the desired level of volume.

Q. And is a variable resistance of that type usually in the form of a resistance on a radio receiver which has a knob which you can turn manually?

A. Yes, that is the usual form of it.

Q. And does the manual operation of that resistance, the manual variation of that resistance control the filament current to all of the tubes in the Wheeler arrangement?

A. It may have a reaction on the filament currents of all the tubes, but its main effect will be to change the filament current of the tube 39.

Q. Do either of the defendant's receivers incorporate this feature in their structure?

A. No, sir.

Q. Now, I call your attention to page 3, line 33, the first column, and will you similarly cover that subject?

> A. "The neutralization of the grid-plate capacity of the radio-frequency amplifying tubes is, in combination with the present invention, particularly valuable in that it allows an increase in the effectiveness of the amplification control, because such neutralization prevents radio-frequency energy from passing through the grid-plate capacity of the tubes."

The amplifying tubes, radio frequency amplifying tubes shown in Figure 1 of the patent are provided with the neutralizing condensers 3, 4, and 28, that is, for the three tubes beginning at the left, first three tubes.

The defendant does not use triodes that is, three

electrode tubes for amplification. Consequently, there is no necessity for provision to neutralize the grid plate capacity which is referred to in this part of the specification.

Q. Are each of the radio frequency amplifier tubes in the defendant's receiver the screen grid type?

A. They are of the screen grid type.

Q. Without attempting to minimize the fact that in the defendant's receivers, that is, in the tube 75 of defendant's receivers, they employ a diode section for automatic amplification control, will you state whether or not it is a fact that the defendant's receiver, or either of them employs a mere diode detector tube?

A. The answer to that question is no. The 75 tube is a combination tube and contains within it a diode section and a triode section.

Q. Referring to the circuits, Plaintiff's Exhibits 2-B and 3-B of defendant's receivers, and with reference to the tube 75, what is the output electrode of that tube?

A. Well, in both instances, it is the anode or plate of the triode section. That is referring to either one of the drawings, where the same thing is shown and underneath the number 75—

Q. The electrode nearest the—

A. The uppermost electrode. It is a horizontal—a short horizontal line, which indicates that plate electrode which is the output electrode of the 75 tube as used in defendant's circuits, both of them.

Q. Now, will you refer to page 3, line 16, column 2 of the Wheeler re-issue patent in suit?

A. The specification there states:

> "The milliammeter 10 is connected in the anode circuit of the amplifying vacuum tube 9. Upon receipt of an amplified signal at the rectifier, the effect of the control circuit is to decrease the

plate current through milliammeter 10, thereby reducing the amplification in the tube 9. When the receiver is tuned to the signal frequency, a minimum amplification is required, so that when the condition of resonance is attained, the plate current of tube 9 is at a minimum value, and the milliammeter 10 so indicates. Thus the milliammeter visually indicates the condition of resonance."

In Figure 1 in the drawing of this patent, the milliameter is located near the left-hand side, and I think it can be most quickly seen by referring to the number 36, which stands out clearly, and going up diagonally to the left a short distance from that. The milliameter 10 is there shown, and as stated in this part of the specification it is connected in series in the anode circuit, that is, the plate circuit of the tube 9, the first one on the left, and it reads the plate current which flows through it, and it is by means of the changes in the plate current of this tube that resonance is indicated.

Q. Now, will you refer to the defendant's circuits in Plaintiff's Exhibits 2-B and 3-B and state first whether or not the visual indicator—I take it back, there is only one that has the visual indicator?

A. That is correct.

Q. Make that 2-B. Right?

A. Yes.

The Court: May I see your 2-B, Mr. Darby?

Mr. Darby: Let me re-frame that question. Withdraw that question.

Q. (By Mr. Darby): Now, will you refer to the drawing of defendant's Model 175, Plaintiff's Exhibit 2-B, and state first whether or not the visual indicator employed in that receiver is located in the same circuit as specified by the Wheeler patent?

A. No, it is not. And, also, it is not a current indi-

cator at all. It is a voltage indicator. The milliameter 10 described in the Wheeler patent is a current indicator in connection—the circuit connection of the device which is used in Exhibit 2-B for indicating resonance is to the automatic volume control direct current connection. If you will look at the resistance numbered 53, which is pretty near the middle of Exhibit 2-B, that resistance 53 is on the direct current connection for automatic volume control. And, proceeding horizontally from that resistance to the left, to the first junction point indicated by an enlarged dot on the line, and then following directly downward on a lighter line, a line that was not emphasized on this exhibit, down to the control grid of the so-called Magic Eye tube, which is indicated here by the designation 606—

Mr. Adams: 605.

A. 605. Thank you. —the indication or, rather, the control of the indication of the Magic Eye tube is from the detector circuit which generates the automatic amplification control potential or voltage, and it is that voltage which directly effects the tuning indicator of the Model 175 receiver shown on Exhibit 2-B.

Q. Now, on page 2 of the Wheeler re-issue patent, the second column, beginning at line 11, is the paragraph which Mr. Davis read to the Court, which recites that the automatic amplification control circuit includes within it a high resistance connected between the filament of the amplifier and the anode of the rectifier, and this same resistance is recited in many of the claims, for example, in claim 1.

Although you have already referred to it before, will you point out the—will you state whether or not either of defendant's receivers employ this resistance so connected?

A. Neither of the defendant's receivers employ this

resistance so connected. If you wish, I will point out the difference.

Q. Yes. Will you please do so?

A. Yes. I made some simplified sketches that I think would probably be a little clearer for this purpose.

Mr. Davis: Will you point it out on Exhibit 2-B, please?

A. Well, I would be glad to do that.

Mr. Darby: If you don't mind, Mr. Davis, I think I would prefer to have him identify the simplified sketch that he has made.

Mr. Davis: Well, I do mind, but I can't stop you, but I wish the witness would. If you don't ask him, I will ask him to point it out on Exhibit 2-B.

A. I would be glad to do that for Mr. Davis.

Q. You would prefer it that way? It would be easier for you, Mr. Davis? Go ahead first on Exhibit 2-B and then on the simplified sketch. I will be glad to cover that.

A. On 2-B, that is, on Exhibit 2-B, what corresponds in function to the resistance 51, that is, as far as generating the rectifying voltage is concerned, is the two resistances which are here labelled 34 and 51 in series with each other. It can readily be seen that a circuit can be traced beginning at the anode of the detector which is here labelled with two numbers, 12 and 35, then passing through the coil which is labelled with the number 31, this coil being the input coil to the detector, and following down, going to the right to the junction point where 34 connects on to that circuit—there is a junction point there, and the circuit branches, one branch consists of the condenser, which is labelled 2 the other branch consists of the sum of the two resistances which are here marked 34 and 51 in series and thence back through the space between the cathode and anode of the detector tube.

The location of the resistance 34 plus 51 in conjunction with the condenser 2 is the combination that generates the rectifying voltage which is later utilized for automatic amplification control and for the purpose of reproducing the sounds, the audio-frequencies.

What particularly I wish to point out is that this resistance 34 plus 51 is not connected between the anode 35 and 12 and the cathode 38, but is connected in such a way that the input coil 31 is interposed between the anode 35 and 12, and the connection of this resistance.

Q. Well, now, having accommodated Mr. Davis in applying it to Exhibit 2-B, have you made a simplified showing of this portion of the defendant's circuit which better illustrates the arrangement?

A. I have here a sketch which I made which is a simplified sketch of this circuit and I think it very clearly brings out what I was trying to describe in connection with Plaintiff's Exhibit 2-B.

Mr. Darby: Just a minute, Mr. Kelley. I had three sets, one for the Court and one for Mr. Davis. Are you working on 175?

A. 175, Defendant's circuit 175.

Q. All right, now, Mr. Kelley, will you proceed?

A. What I pointed out in connection with Plaintiff's Exhibit 2-B I have shown here in simplified form. I think it shows very clearly what the situation is with respect to this high resistance. I made one change in the numbers, the numerals applied to one of the resistances, namely, resistance 34, and called the two in combination, bracketing them, number 51, because there is no correspondence in function of resistance labelled 34 in plaintiff's Exhibit 2-B, and the resistance which is shown in Figure 1 of the Wheeler re-issue patent, also labelled 34, and for that reason I took the two resistances together and called them 51. On the simplified

sketch it is plain to see that the resistance 51 has between it and the anode a coil 31 which is the input coil to the system.

Q. Now, have you made a similar simplified drawing of the defendant's circuit 178 corresponding to plaintiff's Exhibit 3-B?

A. Yes, sir.

Q. Will you please refer to that?

The Court: Just a minute. Will you read back the last statement the witness made?

(The last part of the last answer of the witness was read by the reporter.)

Mr. Darby: Is that clear, your Honor?

The Court: Yes. All right.

A. I also have a similar simplified drawing of the defendant's circuit for the number 178 receiver, and it is precisely the same as the heavy line showing on Plaintiff's Exhibit 3-B, with the exception, with the same exception that the resistance labelled 34 on Plaintiff's Exhibit 3-B I have combined with resistance 51.

Mr. Darby: I offer in evidence the simplified drawing of the defendant's circuit 175, as Defendant's Exhibit U, and I offer in evidence the simplified drawing of defendant's circuit 178 as Defendant's Exhibit V.

(Simplified drawings of Defendant's circuits were thereupon marked as Defendant's Exhibits U and V.)

Q. (By Mr. Darby): Now, have you, to illustrate the similarity or dissimilarity between the automatic volume control circuit employed in defendant's receivers with the automatic amplification control circuit of the Evans patent, made a similar simplified drawing of that circuit in the Evans patent?

A. Yes, sir.

(Simplified drawing of Evans circuit marked Defendant's Exhibit W.)

Q. (By Mr. Darby): Will you please refer to that circuit, which I offer in evidence as Defendant's Exhibit

W, and make the comparison between it and the circuit in defendant's receivers?

A. Yes. First of all, this sketch is prepared from the circuit shown in the Evans patent drawing, that is, Evans patent 1869323, and the numbers that are given to the various elements on this simplified sketch correspond to the numbers that are used in the figure of the Evans patent for those same elements.

This simplified sketch shows the Evans circuit with a triode as it is shown in the figure of the patent drawing. Consequently I have not shown where the signals come in. They come from the left, really, and are applied between the grid of the tube 8 and the ground or filament connection. But the rectified current is produced in the circuit from the anode or left-hand electrode of the tube 8 around through the combination of elements, the output transformer 10, the plate battery 16, and the high resistance 19, all in series with each other, and the combination all shunted or by-passed by the condenser 23, and thence back to the cathode connection.

The rectified current is generated in this circuit, in the resistance 19 for the purposes of the automatic amplification control, and in the transformer 10 for the purpose of audio-frequency amplification, that is applying that to the next amplification tube which would be audio-frequency.

Comparing this with both of the sketches of defendant's circuits, that is, 175 and 178, which are Defendant's Exhibits U and V, the condenser 2 in Exhibits U and V correspond in function to the condenser 23 of the Defendant's Exhibit W. The resistance 19 corresponds in function to the resistance 51. That is, the resistance 19 and the output transformer 10 correspond in function to the resistance 51. There is the difference that plate battery 16 is included in Defendant's Exhibit W since this is shown with a triode for a detector.

Q. Now, is the resistance in 19 in the Evans circuit in Defendant's Exhibit W connected between the anode and the filament or ground?

A. Well, only in the sense that if at all—it isn't my opinion that it is.

Q. That is what I want, your opinion.

A. It isn't my opinion that it is.

Q. Does the interposition of the secondary of the transformer coil 10 between the resistance 19 and the anode—make that is the interposition of this, the reason why you say the resistance is not connected between the anode and the filament?

A. Yes.

Q. Is the Evans circuit the same as shown in both of defendant's circuits insofar as there is interpositioned an inductance coil between the resistance and the anode?

A. Yes, sir.

Q. Now, you have referred to Defentlant's Exhibit W as being employed with a three-electrode tube. Have you also made a simplified circuit showing a rectifier tube in the Evans circuit?

A. I have shown one in which a diode—triode has been changed to a diode by connecting the grid and plate electrodes together.

Q. And is this circuit, which I offer in evidence as Defendant's Exhibit X, the simplified circuit for the Evans automatic amplification control circuit with the diode?

A. Yes, sir. When a diode is used instead of a triode for detection.

(The simplified sketch of circuit of Evans was thereupon marked as Defendant's Exhibit X.)

Q. (By Mr. Darby): And is there any change in the circuit insofar as there being positioned, between the high resistance and the anode, an inductance coil?

A. There is an additional coil in Defendant's Exhibit

X that is, the secondary of the transformer 9 which is the input transformer.

Q. Have you made a similar simplified drawing of the automatic amplification control circuit of the Slepian prior art patent?

A. Yes.

Mr. Darby: I offer in evidence the simplified Slepian circuit as Defendant's Exhibit Y.

(Simplified sketch of Slepian circuit was thereupon marked Defendant's Exhibit Y.)

Q. Does the Slepian automatic amplification control circuit likewise have an inductance between the anode and cathode?

A. Yes, but that inductance is numbered 16, which is the number used on the patent drawing, that is, the Slepian patent drawing.

Q. Will you compare the Slepian simplified circuit, Defendant's Exhibit Y, with the defendant's circuits, Defendant's Exhibits U and V, and point out any dissimilarity insofar as the automatic amplification control circuit is concerned?

A. As far as the detector circuit, which includes the series connection in Defendant's Exhibits U and V of the coil 31, the anode of the diode 12 and 35, the cathode 38 and the combination of the resistance 51 and condenser 2, they, that is, Defendant's Exhibits U and V, are the same as the showing on Defendant's Exhibit Y, which is the simplified drawing of the Slepian circuit. That is, the resistance 9, for example, in Defendant's Exhibit Y, is connected in exactly similar relation to the anode and cathode of the diode 18 as resistance 51 is to the anode and cathode of the diode in Defendant's Exhibits U and V.

Mr. Darby: For convenience of Court and counsel, I have prepared, if your Honor pleases, on a single sheet claim 1 of the re-issue patent in suit, as well as claim

10 of the original patent, in which the parts which are underscored, or stated this way, read by including the parts underscored and omitting the portion in parenthesis, it is claim 1 of the re-issue patent, the basis being claim 10 of the original patent.

Q. (By Mr. Darby): Have you examined this claim as thus set up and checked it with the original and re-issue claims specified?

A. Yes, sir.

Q. You vouch for its accuracy. And have you studied this claim or these claims with respect to the instrumentalities and functions specified for them in the respective patents?

A. Yes, sir.

Q. Are there any different instrumentalities recited in the two claims?

A. No, sir.

Q. Is there any function difference in the two claims?

A. No, sir.

Q. Is there any difference in operation of the instrumentalities recited by the two claims?

A. No, sir.

Q. Is there any difference in the result secured by the instrumentalities as recited in the two claims?

A. No, sir.

Mr. Darby: I ask that the claims as thus compared on this sheet of paper be received in evidence as Defendant's Exhibit Z.

(The sheet of paper containing the claims was thereupon marked Defendant's Exhibit Z.)

The Court: We will take a little rest, Mr. Darby.

(Recess.)

Mr. Darby: I offer in evidence as Defendant's Exhibit AA the wiring diagram of the Colonial receiver which was before Judge Campbell in the R.E.B. case in Brooklyn, involving the original Wheeler patent, using

for that purpose a photostat of the same wiring diagram that was employed in that case.

(The Colonial receiver wiring diagram was thereupon marked Defendant's Exhibit AA.)

Q. (By Mr. Darby): Mr. Kelley, are you familiar with the wiring diagram of this Colonial receiver?

A. Yes, sir.

Q. And understand its operation?

A. Yes, sir.

Q. Will you please briefly describe the automatic amplification control arrangement employed in the Colonial receiver?

The Court: Do you happen to know, Mr. Darby, how old this Colonial was, or what year that came out?

Mr. Darby: I can't tell you right at the moment, your Honor, but I have the record here and would be glad to dig it out and tell your Honor later, if I may, unless Mr. Adams knows.

Mr. Adams: No, I don't happen to know.

Mr. Davis: Of course, it was after the Wheeler patent.

Mr. Darby: After the original Wheeler patent issued, yes, sir, subsequent to 1932.

Mr. Davis: And before the re-issue, of course, because it was in that suit in Brooklyn, which was tried in '34.

The Court: All right.

Mr. Darby: My guess is it was about 1933, your Honor.

Mr. Adams: Just about.

Mr. Darby: Just about 1933.

The Court: All right.

A. I don't believe I have a copy of the circuit. As I understand the pending question you want me to explain the circuit as it pertains to the automatic volume control operation?

Q. That is right.

A. Very well. Referring to this photostat of the

Colonial circuit and particularly to the circuit associated with the third tube from the left, the one that has the number 75 directly over it, and "Det-AVC" under the numeral 75, the detector circuit comprises—

The Court: Just one minute before we get on that. This is a copy of the exhibit that was used in the case before Judge Campbell, you say?

Mr. Darby: Yes, sir.

The Court: Do you recall now where they got this from?

Mr. Darby: It was offered by the Hazeltine Corporation.

The Court: And the wiring chart, that was furnished by the manufacturers?

Mr. Darby: That is right, yes, sir. There is no question as to its authenticity or accuracy, as I understand it.

Mr. Adams: That is right.

The Court: The question I had in mind was as to whether it was something prepared for use in that trial or whether it was a copy of their wiring chart.

Mr. Darby: No, sir; it was a copy taken from their manual or instruction sheet.

Mr. Adams: I think it had some additional labels put on it. You can see some of it is heavier than the rest, and there were some letters like A, F, H, and G, and E and so forth, and I doubt whether they were on it.

Mr. Darby: Those were added by the Hazeltine Corporation.

Mr. Adams: I believe they were.

The Court: All right.

Q. (By Mr. Darby): All right, proceed, Mr. Kelley.

A. The detector circuit comprises a simple series circuit and I will trace it, beginning with the two anodes which are tied together and labelled with a small letter "H", that is of the 75 tube. The circuit then follows

the heavy line up to the left and through the right-hand coil of the transformer and thence to a junction point where the circuit splits before it gets to the cathode. One branch consists of the condenser which is labelled C-9 and the other branch consists of the high resistance which is labelled R-4, and also with the letter K. This resistance and condenser are in parallel to each other, and in series with the detector circuit. At the cathode end of this combination, the circuit continues up to the cathode of the tube, I presume that is a small letter "G" or it may be a number "9".

Mr. Adams: I guess it is a "G".

Q. "G".

A. And up to the cathode which is labelled "g" and thence across the space to the anodes "h", thus completing the circuit.

Q. Did this Colonial receiver employ the same type tube, namely number 75, as is employed in Defendant's sets here challenged to be an infringement?

A. Yes. Both of the tubes used—or the tube used in both of the accused sets is a 75 tube, the same tube.

Q. Have you made a simplified diagram of the automatic amplification control circuit of the Colonial receiver?

A. I have had such a drawing made.

(Simplified diagram of Colonial receiver was thereupon marked Defendant's Exhibit BB.)

Q. Now, will you compare this simplified drawing of the Colonial set, which I offer in evidence and asked be marked Defendant's Exhibit BB, with the simplified drawing of Defendant's receivers here charged to be infringements, namely, Defendant's Exhibits U and V? I think maybe I can short cut it, insofar as the use of the tube—insofar as the vacuum tube itself is concerned, and insofar as the automatic amplification control arrangement is concerned, is the Colonial receiver the same

as or different from the defendant's receiver 175 here before the Court?

A. It is the same, and just for provision—it is a minor difference—the connection on Defendant's Exhibits U and V which goes back to control the amplifier is at an intermediate point on the resistance 51, whereas in the Colonial set, simplified drawing, and in the set, of course, it includes the entire resistance 51, but this is a minor detail.

Q. Does that effect the automatic amplification control?

A. No.

Q. Is the same true with respect to Defendant's Exhibit V, representing in simplified form Defendant's 178 model?

A. It is the same.

The Court: What was the letter of this last exhibit?

Mr. Darby: This last exhibit was Defendant's Exhibit BB.

A. DD?

Q. BB. Now, Mr. Kelley, have you examined the wiring diagrams of Defendant's Exhibits D to R, inclusive, which are the wiring diagrams introduced as part of the stipulated testimony in this trial, representing the various circuits incorporated in defendant's receivers since the inception of the defendant company?

A. Yes, sir.

Q. I have asked you to select from those wiring diagrams of receivers manufactured prior to the application for the re-issue patent here in suit, models which, in your opinion, were similar to the receivers here charged to infringe insofar as automatic amplification control arrangement is concerned. Have you done so?

A. Yes, sir; I have done so and the receivers are shown, receiving circuits shown on Defendant's Exhibits D and G. They are the ones I selected.

Mr. Darby: Then I may note, if your Honor please, that Defendant's Exhibit D is known as the Detrola Warwick model, and Defendant's Exhibit G was known as the Detrola Model 1200.

Q. (By Mr. Darby): Have you had prepared simplified wiring diagrams of the Detrola Warwick Model D insofar as the amplification control arrangement is concerned?

A. Yes, sir.

Mr. Darby: I offer the simplified diagram in evidence as Defendant's Exhibit CC.

(The simplified diagram above referred to was thereupon marked Defendant's Exhibit CC.)

Q. (By Mr. Darby): Will you compare Defendant's Exhibit CC with the defendant's receivers here challenged, the simplified diagrams, Defendant's Exhibits U and V, and state whether they are the same insofar as automatic amplification control arrangement is concerned?

A. They are the same.

Q. Have you similarly had a simplified diagram made of Defendant's Exhibit G, the Detrola Model 1200?

A. Yes, sir.

Mr. Darby: I offer this simplified diagram in evidence as Defendant's Exhibit DD.

(The simplified diagram above referred to was thereupon marked Defendant's Exhibit DD.)

Q. (By Mr. Darby): Will you state on comparisons with Defendant's Exhibits U and V, the simplified wiring diagrams of the two defendant receivers here challenged, whether they are the same or different insofar as automatic amplification control is concerned?

A. They are the same.

Q. I notice one difference in that there is in Defendant's Exhibit DD, there is an inductance coil connecting the two anodes 35 and 12 and the automatic amplification control circuit is connected to a mid-point in that

inductance. Does that difference make any difference in the automatic amplification control operation?

A. No, that connection simply makes the pair of anodes, 12 and 35, full wave rectifiers instead of half wave. In other words, it is a full rectification by the method of utilizing the rectified current and precisely the same.

Q. Is the circuit employed for utilizing the rectifier current the same?

A. Yes.

Mr. Darby: Merely to have in evidence something which may prove to be of convenience to everybody, I offer in evidence as Defendant's Exhibit EE a diagrammatic picture of the multi-purpose vacuum tube, similar in general construction to the tube 75 with which we are here concerned, and also tube 6B7, I believe. I will state for your Honor that this likewise was an exhibit employed in the prior case and I believe was offered in evidence by the plaintiff. As I understand it, they don't question its accuracy.

Mr. Adams: That is right.

Mr. Davis: It is an R.C.A. bulletin, isn't it?

Mr. Darby: I think so, yes, but I think it gives a clear picture of just what the internal construction of these multi-purpose tubes are, insofar as we are concerned with them.

You may inquire, Mr. Davis, but I might say that I have one very short witness, that Mr. Davis has kindly consented to allow me to put on before he undertakes the cross examination of Mr. Kelley, if your Honor has no objection.

The Court: Go ahead.

Mr. Crews: Mr. Gates.

HOWARD A. GATES, a witness called on behalf of the Defendant, having been first duly sworn by the Court, testified as follows:

Direct Examination

By Mr. Crews:

Q. Mr. Gates, will you please state your age?
A. 34.
Q. Your residence?
A. 7760 LaSalle, in town.
Q. Detroit?
A. Detroit.
Q. And your occupation?
A. I am vice-president in charge of engineering of the Detrola Radio Corporation.
Q. How long have you been with the Detrola Company?
A. Since late in the year '35.
Q. Are you responsible for the markings of patent numbers on the sets manufactured by the Detrola Company?
A. I am.
Q. What is the policy of the company in that respect?
A. When I came to the Detrola Corporation they had practically no engineering department and very few drawings, and they were using a license plate, I don't know exactly the origin of it, but I agreed to use all of the material that I could use, and we continued to use that plate for some time after I had associated myself with the company and until I wrote to R.C.A. sending them the circuits we were then using and got a revised list. Then I changed that plate incorporating the revised list of patent numbers applied to the receiver.
Q. Have you brought with you the print showing the

numbers that you were applying to receivers at the time you went with the Detrola Company?

A. I have.

Q. Will you please produce it?

A. (Producing document.)

Mr. Crews: I offer in evidence the list produced by the witness as Defendant's Exhibit FF.

(List of patent numbers was thereupon marked Defendant's Exhibit FF.)

Q. (By Mr. Crews): Now, Mr Gates, did I understand you to say that this was the marking that you applied to all sets made by the company?

A. Yes, the same plate was applied to all sets.

Q. Regardless of what circuit those sets contained?

A. That is correct.

Q. And regardless of any different instrumentalities they might contain?

A. That is correct.

Q. All right, then. You were telling me that you continued to use that plate until you got further instructions. Will you continue your answer and tell us about that?

A. Well, I used the original plate until I used most of them up. Then, based on the letter I wrote to R.C.A. and based on circuits I sent them and the revised list of numbers they sent me, we changed the plate and, of course, used that on all receivers thereafter.

Q. And have you brought with you the list referred to showing the markings then used?

A. I have.

Q. At about what time did you start using this new list?

A. 8/12/37.

Q. You mean August 12, 1937?

A. That is right.

(List of patent numbers was thereupon marked Defendant's Exhibit GG.)

Mr. Crews: I offer in evidence the copy of list just produced by the witness as Defendant's Exhibit GG.

Q. (By Mr. Crews): How long did you continue to use this list of numbers? Just continue with your story.

A. Well, I continued to use the revised list until R.C.A. voluntarily sent a further revised list. This was addressed to Mr. Ross and received by the Detrola Corporation October 20th, '37. However, based on the fact that I had already used the revised list, and had plates in stock, I continued to use those plates before another change was made.

Q. And how long did you continue to use the old plates?

A. Well, the second plate, we continued to use for almost a year.

Q. That is, the plate of Exhibit GG, dated August 12, 1937, you continued to use for almost a year after you received a new list from the R.C.A. under date of October 20, 1937?

A. That is correct.

Q. Yes. Now, have you brought with you the list you received from the R.C.A. under date of October 20, 1937?

A. I have.

Mr. Crews: I offer in evidence the list produced by the witness as Defendant's Exhibit HH.

(List of patent numbers was thereupon marked Defendant's Exhibit HH.)

Mr. Crews: I have no copy of that, but I have this particular sheet, and I have another document here that shows the identical numbers that are on this sheet.

Q. (By Mr. Crews): When did you change your markings to the list on Exhibit HH?

A. That was changed 10/21/38.

Q. And did you bring with you a print showing the change that you made at that time?

A. I did, and this is the plate that has been used on all sets from that time on.

Mr. Crews: I offer in evidence a copy of the plate produced by the witness as Defendant's Exhibit II.

(List of patent numbers was thereupon marked Defendant's Exhibit II.)

Q. Has it been your policy throughout the period of your connection with the Detrola Company to use a single plate at any one time on all models made by the company, regardless of any differences between those models?

A. We have always done that, used one plate for all sets.

Mr. Crews: That is all, Mr. Gates. Just a moment. There may be some cross examination.

Mr. Davis: May we have the witness remain here until afternoon, and we won't interrupt now to discuss this testimony. If you will be here this afternoon then I will go ahead with cross examination.

(Witness excused until afternoon.)

LEO A. KELLEY, was thereupon recalled as a witness on behalf of the Defendant, being previously duly sworn, testified further as follows:

Cross Examination

By Mr. Davis:

Q. Mr. Kelley, will you turn to the wiring diagram

of the Evans patent 1869323?

A. You mean the figure of the patent, sir?

Q. Yes. I direct your attention to the battery marked 16. That is the plate circuit battery of the detector 8, isn't it?

A. Yes, sir.

Q. Commonly known as the "B" battery?

A. That is correct.

Q. And commonly employed in all three electrode detectors and amplifiers?

A. That is correct.

Q. Is the plus or the minus terminal of the battery connected to the anode of the tube 8?

A. The plus terminal.

Q. So that the effect of the battery is to place a positive potential on the anode 8?

A. Yes, with respect to the cathode of the tube.

Q. And the cathodes of all these tubes may be assumed to be grounded, isn't that correct?

A. They may be assumed to be either at ground potential or near ground potential.

Q. So that the effect of connecting the positive terminal of the battery 16 to the anode of the detector tube is to maintain the anode at a positive potential with respect to its own cathode, and also with respect to the amplifier cathodes, is that correct?

A. That is the purpose of the battery, yes, sir.

Q. And it is its effect, isn't it?

A. Yes. There is some difference, however, in the operation as to the effect of the battery 16 in its anode circuit as compared, for example, with the battery 15 which is similarly a plate battery associated with the anode circuits of the amplifier tubes 4 and 5 in this respect; that the polarity which is developed in the resistance 19 is in opposition to the polarity of the

battery 16 and thereby subtracts from it as far as the over-all voltage in the plate circuit is concerned, but the net result will be that there will be some positive potential applied to the plate. What I mean to say is that it won't be a fixed value of the value of battery 16.

Q. And the effect of putting this positive potential on the anode of the detector 8 is to attract the negatively charged electrons that flow from the cathode or filament of that detector, is it not?

A. Precisely.

Q. So that the stream of negatively charged electrons flows across from the filament of tube 8, being attracted by the positive charge on the anode, which positive charge comes from the battery?

A. That is correct. It is not the whole story as to the operation of the tube, because you haven't mentioned the effect of the grid upon that.

Q. Yes.

A. But so far it is correct.

Q. Now, those negative electrons come from the battery 16 do they not?

A. That is the source of energy, yes, sir.

Q. And they flow from the negative terminal of the battery 16 which is the heavy, shorter black line at the right-hand end of that battery, and they flow from that terminal to the right, as far as the spot with the minus sign above it, then down through the resistance 19 and to the ground and thence to the cathode of the tube and across the gap in the ~~tube~~ to the anode and back to the negative terminal of the battery 16, is that right?

A. You mean the positive terminal?

Q. The positive terminal, excuse me.

A. That is the direction in which the electrons progress, which is the opposite direction from which the current flows. If you wish, I will explain it.

Mr. Davis: No. I don't know why you introduce that complication. I may say, your Honor, that in the good old days when they didn't know about electrons, the learned gentlemen who called the thing positive and negative had to guess, and there were only two chances. They either had to guess right or wrong, and it happened that they guessed wrong, so that when they talked of the directional flow of the current, it just happens to be from that historical circumstance the opposite of the directional flow of the electrons, as we now know, is that about right?

A. That is exactly what I had in mind.

Q. Now, it is the flow of that battery current through the resistance 19, or perhaps I should say the impedence of the resistance 19 to the flow of the battery current that builds up at that minus sign the negative potential which is used for the A.V.C. control potential in the Evans arrangement, is it not?

A. That is generally true, but it is not in the same sense as we ordinarily think of potential being built up by a battery being connected in circuit where there is resistance, because there is included in series with the resistance 19 what you might call the variable resistance of the detector which controls that.

Q. Well, I think I agree with that. But, nevertheless it is the flow of current of the battery—

A. The battery is the source.

Q. —that builds up your negative potential?

A. The battery is the source of the current for that purpose, yes, sir.

Q. That is, in the Evans system, the automatic volume control potential is produced by the flow of the battery current from the battery 16, isn't it?

A. In the sense that we have discussed it, yes, sir.

Q. Now, let's look at the grid circuit of the tube

8. The battery 17 has its negative terminal connected to the grid; is that right?

A. That is correct.

Q. And its positive terminal connected to the filament circuit?

A. That is right.

Q. So that impresses a negative potential on the detector grid; is that right?

A. Yes, sir.

Q. And that potential being of a value determined by the battery 17?

A. That potential, yes, sir.

Q. And that potential acts as a shutter, as Mr. Wheeler described it—as he spoke of it, I thought of a Venetian blind, for instance,—the negative charge on the grid acting to depress or prevent the flow of these electrons from the filament to the anode of that detector tube; is that right?

A. I think I could clarify it a little bit.

Q. Yes. Will you do that, Mr. Kelley?

A. It does not actually prevent the electrons from flowing to the plate, of course. Otherwise, there would be no plate current. But it does, as you say—it tends to prevent their flow, yet allows an opening for the electrons that are not completely restrained, and of their own momentum to go through and reach the influence of the plate and be drawn to it.

Q. Well, it is possible to put upon the grid of a detector tube a sufficiently high potential to shut off the plate current altogether, isn't it?

A. Yes, it is possible, but usually in most applications there has got to be a flow of plate current, at least during the operation, in order to get a response.

Q. Any useful effect?

A. But you can purposely put sufficient negative

potential on the grid to shut off this flow of electrons completely.

Q. Well, that means, doesn't it, that the grid battery 17 in the operation of this detector has to be adjusted with respect to the plate battery 16 so that the detector will operate correctly?

A. That is correct.

Q. Now, in order to get a detecting action, that is, in order to shut off the negative impulses but pass the positive impulses of the signal in this Evans system, how does that adjustment have to be made? Can you tell me that?

A. The adjustment is made by having the correct relation between the battery 17 and the battery 16.

Q. Yes. And what is that correct relation? I mean to say, on what point of the characteristics is the adjustment made?

A. It may be made all the way—it may be made all the way to cut off, that is to say, to the full amount of the negative voltage that would stop electrons from flowing to the plate, or it may be on the curved lower portion of the plate current characteristic.

Q. Well, you mean it must be pretty near the cut-off point in order to act as a detector?

A. It will be in that general vicinity.

Q. And in that general vicinity the—or, with it in that general vicinity, I will put it that way, the effect is this, as I understand it: That when a negative impulse from the signal is impressed on the grid, adding to its already negative charge from the battery 17 the effect is to increase the negative charge to the point of cutoff, whereas when the positive charge from the signal, that is, the positive half of the carrier wave is impressed on the grid, that merely reduces the nega-

tive charge due to the battery 17 and permits electrons to flow in the plate circuit; is that right?

A. That is right.

Q. And it is in that way that in this Evans system, with the proper balance of battery 17 with respect to battery 16 you control the flow of energy from the battery 16 through the circuit which includes the resistance 19; is that right?

A. That is right.

Q. That is, in this Evans arrangement the signal controls the amount of energy that is released from the B battery 16?

A. Yes; in the circuit shown in the drawing, that is true.

Q. Now, you spoke a while ago of a different situation of the battery 15 with respect to the battery 16. The fact is that the negative terminal of battery 15 is connected to the filament, isn't it?

A. Yes, sir.

Q. That is, to ground?

A. Yes.

Q. Whereas the resistance 19 is interposed between the negative terminal of the battery 16 and ground?

A. Yes, sir.

Q. And that means, does it not, that you can't use the same battery as both 15 and 16?

A. No, you can't use the same battery for both purposes.

Q. Now, as I understand it—and I am going to use a figure to make it easier, I mean to give it positive value—let's assume, if we may, that the control potential that we want on the amplifier grid in any of these sets is 10 volts. With that assumption I will discuss this Evans circuit.

In other words, the assumption is that the potential

impressed on the grids of the tubes 4 and 5, by reason of the inclusion of the resistance 19 in that circuit of the battery 16 is 10 volts. Now, that potential is equal, as I understand it, to the product of the value of the resistance multiplied by the value of the current that flows through it?

A. That is right.

Q. That is, that is Ohm's Law. I learned it C is equal to E/R. And the result is that the electromotive force is equal to the current multiplied by the resistance always?

A. That is right.

Q. Now, we are assuming that in this arrangement in which battery current is flowing through the circuit under the control of the grid, that there is enough current flowing through the resistance 19 to make up the potential of 10 volts on the amplifier grids.

Now, suppose I don't have the battery there, and don't have the battery current and consequently have a lesser current flowing through the circuit. What have I got to do to the resistance 19 to make up the potential of 10 volts?

A. I don't think I got quite the situation there.

Q. Well, I don't wonder.

A. Pardon?

Q. I will put it in a more simple way, Mr. Kelley. It follows from Ohm's law that if the resistance—that if the current in that circuit is reduced to a lower value, then the resistance 19 must be correspondingly higher in order to produce the 10 volts on the amplifier grids?

A. That would be true.

Q. Now, when you look at the defendant's circuit, I will refer to Exhibit 2-B, you don't find in that circuit any such battery as battery 16, do you?

A. No, sir.

Q. Nor any such battery as battery 17?

A. No, sir.

Q. Nor any balancing of the voltage of one such battery against the other in order to determine the negative potential on the grid of any tube, in fact, there is no grid?

A. No.

Q. In the defendant's system?

A. That is right.

Q. In that tube?

A. That is right.

Q. Now, I want to trace how the potential is produced in the defendant's set without the battery 16. As I understand it, the amplified signal which has been amplified in the radio-frequency or intermediate frequency stages of the amplifier is impressed through the coil that is marked 31 here upon the input circuit of the grid detector of the defendant's set, is that right so far?

A. Well, I would state it slightly different, but generally it is right.

Q. Well, Mr. Adams says I should say the diode detector which I guess I should, that is right, isn't it?

A. It is. It is the diode section of that 75 tube.

Q. Now, so far we have no—we have brought out I mean that we have no grid between the cathode and the anode on the diode section of the defendant's detector. There is no negative potential impressed in that space, that is right, isn't it?

A. No, there is none.

Q. As I understand it, however, that there is in such a situation, because of the hot filament or cathode 38, there is a small space current, as they call it, that is, a small flow of electrons from the filament or heated cathode 38 across the space to the anode marked 35-12

and that flow occurs even when no signal is present, is that right?

A. Yes.

Q. Now, that has the effect to impress what sort of a potential upon the anode 12?

A. A negative potential.

Q. In that respect this arrangement is unlike the Evans patent, that is, where the battery in Evans is putting a positive potential on the anode, in the defendant's system this flow puts a negative potential on it, is that right?

A. Well, I think that the difference that you are drawing there doesn't quite tell the whole story.

Q. I think not.

A. Because actually in the drawing of the Evans patent it is the plate battery 16, that is true, and it is likewise true in the tube 8, as a triode, as it is shown in the drawing, that if no control potential were applied to the grid there would also be, due to the same cause as you referred to in connection with the diode of the cathode 38, that is, the fact that when it was heated it would give off electrons and from this would reach—and some of this would reach the anode, would be similarly true in a diode, except for the control exercised by the grid.

Q. In a triode, you mean?

A. In a triode.

Q. Well, all you are saying now, Mr. Kelley, is that if you take the plate battery and the grid battery away from a triode, I suppose you are leaving the grid connected to nothing at all, that there is then no grid action in it, is there?

A. That is right.

Q. But that is not the way they used it in the Evans system, is it?

A. That is not the way it is shown in the Evans drawing.

Q. Now, to come back to how this control potential is produced in the defendant's system, you have already said that when no signal is present, there is, because of this space current across the tube, a slight negative potential on the anode 35-12. Now, when the signal increases and the diode passes the positive impulses of the carrier, the effect is to permit more electrons to flow and to build up more of a negative potential on the anode 35-12, isn't it?

A. Yes, sir.

Q. In proportion to the amplified signal itself?

A. Yes.

The Court: Let me hear that question and answer.

(The last two questions and answers were read by the reporter.)

Q. That is, Mr. Kelley, as I understand it, the energy of the amplified signal itself builds up then on the anode of the amplifier—of the detector—an increasingly negative potential due to the fact that the detector will let through the impulses of the carrier wave in one direction and not in the other?

A. Yes.

Q. And that energy of the signal so built up into a potential on the anode 35-12 is accompanied by the flow of the negative charges of the electrons from the cathode to the anode of the detector itself, is it not?

A. Yes.

Q. Now, that negative current in the defendant's set flows down, that is, flows over to the left, down through the coil 31, over to the junction point, and I will follow the split that goes down now, down through the resistance 34, over through the next junction point 52, down through the resistance 51 and to ground and

through the ground back to the cathode 38, is that right?

A. That is right.

Q. And it is that energy of the signal itself that builds up across the resistance 51 the control potential that is led back to the amplifier grids, that is right, isn't it?

A. That is the source of energy for that purpose.

Q. Well, it is right that in the defendant's set the whole potential is created wholly out of the amplified signal itself, whereas in the Evans system the control potential is created, carved, if you please, out of the energy of the "B" battery 16, isn't that right?

A. No, that is not a correct statement. The first part of your statement with respect to the amplified signal being the source of energy is perfectly correct in defendant's circuit, but when you come to the drawing of the Evans patent, the incoming signal there, the amplified signal there is—the voltage variations of it are actually amplified through the agency of the tube acting on the plate current stream. The only reason for the battery 16 beiug in there is because of the amplifying action.

Q. Well, precisely so. That is, the amplifying action is a relay action which consists in using the amplified signal, not to create the potential directly, but to control the current of the B battery and so produce an amplified control potential indirectly. Isn't that right?

A. I don't know whether you just said it the way I had it in mind, but what I had in mind was that it is the incoming signal amplified which controls the current in the plate circuit.

Q. That is right.

A. And I think maybe we have said the same thing. But I prefer it that way.

Q. The point being that in the defendant's system, the control potential is created from the amplified signal itself without the interposition of any extaneous electromotive force at all?

A. That is right.

Q. In the Evans patent, on the contrary, the amplified signal is used to control the electromotive force of an extraneous battery, that is the battery 16, and to make the control potential out of that. Isn't that right?

A. Well, that is as shown in the drawing, and that is what you do with a three electrode tube.

Q. In the respects which we have just been going over, the defendant's steps correspond, do they not, to the system shown in the Wheeler patent rather than to the system shown in the Evans drawing?

A. You mean in respect to the whole energy being due to that of the amplified signal?

Q. Yes.

A. In that respect, yes, sir.

Q. Well, that is because in Wheeler and in the defendant's system, the controlling potential is created by passing the energy of the amplified signal through a two electrode detector which has properly connected to its circuit this high resistance 51, sufficiently high so that that energy produces the desired potential at the control grid?

A. Would you please read the question again? It is a little bit involved.

(Question read.)

A. There is a high resistance included in both cases, but in different circuits, so that while, generally speaking, the same function is performed, it is by means of two different circuits. That is, defendant's circuit is different from that shown by Mr. Wheeler in his patent.

Q. Well, will you look at Exhibit 2-B. It is the re-

sistance marked 51 by Professor Hazeltine on that diagram which produces the potential, the control potential that is led back to the grids of the amplifying tubes, isn't it?

A. That portion of the control potential which is developed across that resistance is what goes back. There is a potential, of course, created across the entire combination 34 and 51 of the same character, only larger.

Q. Yes. But the portion of it that is developed across the resistance 34 is not led back to the control grids, is it?

A. That portion is not led back. In other words, the part that is led back does not take in the entire amount developed in the high resistance.

Q. Well, the part led back, Mr. Kelley, is the control potential, isn't it?

A. That is the part that is used to control the potential, yes.

Q. And that control potential is developed in defendant's set across the resistance that Professor Hazeltine has marked 51, isn't it?

A. That is the portion, yes, but the resistance 34, in my opinion, should be included with the one that is marked 51, in order to designate the function of that part of the circuit.

Q. Why should it be when 34 does not produce the potential, the control potential?

A. Because 34, in series with 51, is a very essential part of the production of the potential across 51.

Q. Well, I noticed that when you were producing this diagram of the Colonial set, which you said was the same, and on looking over the diagram, that is Exhibit AA, I saw that there was no resistance corresponding to 34. What have you got to say about that?

A. Well, if it is as I recall it, the entire voltage across the resistance is there used. I mean the voltage across the entire resistance is there used.

Q. Well, then, a separate resistance, or a separate portion of the resistance across which the control potential is not developed, is not essential to the operation of these sets, is it?

A. It depends entirely on the design. That is, with a given set, it may not be—in a given tube it may not be necessary to employ the entire potential developed, and, as in a common ordinary potentiometer connection, to use a portion of it.

Q. Well, I am not so much concerned, Mr. Kelley, with what letters you put on these sections of the resistance, as I am to have you agree with me, if I am right, or disagree if I am wrong, that it is the resistance marked 51 by Professor Hazeltine, that, in defendant's set, produces the control potential, just as in Wheeler's patent his resistance 51 produces the control potential. That is right, isn't it?

A. Well, I don't agree entirely because the production of that potential involves the whole detector circuit operation, and to say that it produces that potential without any qualification whatever, is not correct, but to say that that portion of the total resistance across which the control voltage is developed—you see what I mean, Mr. Davis?

Q. Yes, I do. Suppose I put it this way so that we are sure we understand one another. You agree that in the Wheeler patent the resistance 51 has a function to take part in the production of the control potential. That is right, isn't it?

A. That is correct.

Q. And in the defendant's set 175, the portion of the resistance marked 51 by Professor Hazeltine, is that

resistance which has the corresponding function in the production of the control potential?

A. I don't know how broad you are using the expression "corresponding function".

Q. All I want to get at—I am not trying to phrase a question that will say more than it should—all I want to get at is that the portion of the resistance 34 which you marked 51 in your simplified diagrams, does not—it is not the drop across 34 plus 51 that produces the control potential in the defendant's set, but merely the potential drop across 51?

A. It is the potential drop across 51, over which 34 controls, as well as 51 controls the amount of flow of current.

Q. Yes. It is in series.

A. I don't see how you can take 34—how you can disregard 34 when you say you produce—that the voltage produced for automatic amplification control is due to 51 alone, that is, because the way the voltage is produced in 51 is by a flow of current through 51 and the flow of current through 51 is limited also by the flow of current through 34.

Q. That is right. And 34 is, however, a fixed resistance, isn't it?

A. That is perfectly correct.

Q. Now, also in series in that circuit in both the Wheeler patent and in the defendant's sets, is the resistance of the diode itself; is that right?

A. Yes.

Q. That is, the resistance between the anode and the cathode of the detector tube.

A. I would modify that a little bit, in fact, quite a lot, because the resistance in the plaintiff's Exhibit 2-B, that is, the Model 175 drawing, the resistance we are speaking of is in series with the diode but in a different

series circuit from that in which resistance 51 in the Wheeler patent is in series. They are two different circuits.

Q. You have already said that. But what I was asking is this; that in series with the resistance 51 and resistance 34 in the defendant's circuit, there is the resistance of the diode?

A. Yes.

Q. And there is also the resistance of this coil 31, isn't there?

A. Yes.

Q. Now, let me ask you something about the qualitative value of these things. The resistance of the part 51 in the defendant's set is said to be half a million ohms, is that right, 500,000 ohms?

A. Yes.

Q. And the resistance of 34 is one-tenth of that, that is 50,000 ohms?

A. I think that is correct. At any rate, it is marked on the drawing.

Q. And what do you say is the average resistance of the detector tube?

A. Well, it varies.

Q. I know it varies, but can't you give me an order of magnitude.

A. I would say 5,000 ohms or so.

Q. And what would you say would be the resistance of the secondary coil of the transformer 31?

A. Well, the resistance, the direct current resistance would be only a matter of a few ohms, but the circuit has besides—the circuit has to carry not only direct current, but also currents of varying frequencies, audio-frequency currents, radio-frequency currents, for which condition the impedence value of the coil 31 will vary considerably.

Q. Yes, but for this direct current component which produces the control potential, the resistance of that coil is only a few ohms, isn't it?

A. For the direct current.

Q. Yes.

A. It would be only a few ohms.

Q. In comparison with the resistance 51 which is half a million ohms, that is right, isn't it?

A. For direct current?

Q. Yes.

A. That is right.

Q. Now, for the direct current, that is a negligible difference, isn't it?

A. That is true, for direct current.

Q. Well, all right. Now, we understand you to say that for the alternating current components, that is a different effect or different answer to the question. I understand that, Mr. Kelley, and I am not trying to get you away from that. I am talking now about the direct current component of the energy in that circuit, and for that direct current which produces the control potential the resistance of 31 is negligible, isn't it?

A. I will say the resistance of 31 is negligible at direct current.

Q. Now, the resistance of the tube, the detector tube, you say varies. What do you mean by that?

A. Well, I mean to say that in conducting current in one direction it is practically infinite and the other direction has a finite value which isn't precisely the same at all values of voltage.

Q. And it varies also with the tubes, doesn't it?

A. Oh, yes.

Q. Well, now, this variable resistance of the diode is in series with the fixed resistance 51 and 34, isn't it?

A. Yes, sir.

Q. Now, actually the voltage available from the signal here divides itself according to the different resistance in those two tubes, I mean according to those two difference resistances, is that right?

A. I don't think I understood what you meant to say.

Q. Well, I will get it the other way. Let us go back to this Evans patent. Now, in that Evans patent the resistance 19 and the resistance of the triode are in series, are they not?

A. The plate resistance of the triode and resistance 19 are in series.

Q. Yes. What do you mean by plate resistance?

A. I mean the same sort of thing we were speaking of in connection with the diode.

Q. That is, the resistance across the tube from cathode to plate?

A. That is right, through the space.

Q. And it is really that resistance that is controlled by the grid in the triode system, isn't it?

A. No, it is really that controlled by the incoming signal which in turn is through the agency of the grid.

Q. Well, let us assume that we set up this system of Evans so as to give us the desired potential for control, I will say 10 volts again, and I have made that adjustment of all the parts, including the battery 16 and 17 so as to give me the desired voltage of 10 volts. Now, suppose I change the internal resistance or the plate resistance, which I think you call it, of the triode detector 8. I am going to change it by making it greater. What effect would that have upon the signal, the control voltage?

A. That would reduce the current flowing in their through the resistance 19 and hence lower that voltage.

Q. And if I make the resistance of this triode less

what would be the effect?

A. Well, there would be a greater current flow and an increase.

Q. And the contr. potential would be higher than I had intended?

A. Yes.

The Court: All right. This may be a good place to stop. Two o'clock.

(Thereupon, a recess was taken until 2:00 o'clock P. M.)

Detroit, Michigan,
Tuesday, October 31, 1939,
2:00 o'clock P. M.

Court met pursuant to recess.

LEO A. KELLEY, was thereupon called as a witness on behalf of the Defendant, being previously duly sworn, testified further as follows:

Cross Examination (Continued)

By Mr. Davis:

Q. Mr. Kelley, I want to get you to help me out, if you will, on this matter of linear detection. As I understand from your testimony, you agree that a diode detector used in series with a high resistance as in the Wheeler patent and as in the defendant's sets, will give linear detection?

A. Yes, sir.

Q. And that the result of that is that the energy

of the signal itself is caused to create a potential for control and that potential is maintained directly proportional to the energy of the amplified signal itself?

A. That is not true of linear detection in all instances. It is true where the diode is concerned.

Q. And it is true in the Wheeler system and in the defendant's set?

A. Yes.

Q. Now, you referred to the patent to Major Armstrong—the number is 1716573—in which he dealt with getting a linear characteristic out of the diode, and I direct your attention to the second page of that patent, the first column, beginning in line 29, where, referring to the principle of his invention which has previously been described, he says:

> "In the application of this principle to practice, a hitherto unsurmountable difficulty has been encountered because of the shape of all rectifier characteristics. The preceding theory assumes a straight line characteristic for the detector—that is, that the rectified or low frequency current is proportional to the amplitude of the high frequency electromotive force impressed upon it. The actual characteristics of detectors follow the square law; that is, the rectified current is proportional to the square of the high frequency electromotive force impressed upon it."

Now, that application was filed in 1922. You know what Major Armstrong meant by that?

The Court: Mr. Davis, I didn't get the place where you were reading.

Mr. Davis: I am sorry.

A. I didn't, either, Mr. Davis.

Q. Page 2, line 1, or column 1, line 29.

A. I have it now, thank you. Well, that simply means that in the application to his particular scheme he requires linear detection.

Q. But what Major Armstrong said there in 1922 was that all detectors—and I think you will agree he was considering both the diode detectors and the triode detectors, follow the square law and do not produce linear detection. Do you know why he should have said that in 1922?

A. I think probably because or largely because of low signal detection. That is, the receiving sets of those days did not have very much amplification preceding detection.

Q. And so that the signal to be handled in the sets of those days was quite small, so small that it was detected on the lower part of the detector curve where the response is a square law response; is that right?

A. Yes, and I am thinking when I say that particularly of radio receiving sets as distinguished from, for instance, carrier wave systems generally.

Q. I think you said yesterday to us that both the diode detectors and the triode detectors responded according to the square law for very small signals. That is right, isn't it?

A. That is correct.

Q. Now, your thought is that it was—that Major Armstrong made this general statement that both those detectors had a square law and not a linear response because in those days the signals handled were so small that they did not get into the linear section of the diode or the detector of either form; is that your idea?

A. Well, that is a long time ago, but I think that is a reasonable understanding of what he had in mind.

Q. Well, now, you were out of college at that time, weren't you?

A. Yes, sir.

Q. You were with the Western Electric Company?

A. Yes, sir.

Q. You were working with these diodes, weren't you, right along?

A. Yes, sir.

Q. With the triodes?

A. Triodes, yes, sir.

Q. I guess you were not working with the diodes, were you?

A. We did use diodes, yes, sir.

Q. Not as detectors?

A. As rectifiers.

Q. But not as detectors?

A. Well, the terms "rectifier" and "detector" are used synonymously.

Q. I am not talking about the name you applied to the devices. Isn't it true, Mr. Kelley, that at that time you nor anyone else you knew of, used a diode as a radio detector in any radio receiving set?

A. I don't know that nobody did, but I didn't.

Q. And you don't know of anybody that did?

A. In a regular receiving set, no.

The Court: Mr. Davis, may I interrupt you a minute?

Mr. Davis: Yes.

(Slight interruption.)

Q. (By Mr. Davis): Well, this patent in which Major Armstrong disclosed how to get a linear characteristic from a diode did not issue until June, 1929. Do you know whether prior to that time you knew how to get a linear characteristic response from a diode detector or rectifier?

A. I am sure that I did, although I don't have a definite recollection of what time that would be.

Q. What is it in your recollection that makes you sure it was prior to 1929?

A. Well, I am sure of it.

Q. You just feel morally certain?

A. Well, now—

Q. Well, I am really not so much interested, Mr. Kelley, I just wondered if there was anything that stood clear in your memory when you first found out that a diode could be used to produce a linear response when used as a rectifier or detector?

A. Well, that is what I was trying to do and, I don't seem to have anything clear in my mind on that.

Q. Well, now, still having in mind the question of this response, of different kinds of detectors and rectifiers, and will you turn back to this drawing of the Evans patent and I want to bring into the discussion the question of overloading, Mr. Kelley, see if I understand that. It has been said here, and I suppose you agree, that the triode detector as it was commonly used at the date, May, 1923, of this Evans patent application, would respond on the square law for a weak signal and would be overloaded by a strong signal?

A. Only under special conditions and for a portion of the characteristic between what you refer to as the square law and overloading condition the characteristic approaches linearity.

Q. I think if you will you can make that a little clearer. I think I understand it, but refer to the curve of the response, which is Figure 2—

Mr. Adams: Figure 4.

Q. Figure 2 of the patent, is it? There are two curves. I have got the original patent instead of the re-issue here.

Mr. Adams: Diode versus triode curve.

Q. Figure 4, that is right, of the re-issue patent in suit. Now, as I understand it, the very lower part of that black curve which at that part represents both a

diode and a triode, and which lower part is flattening out as it approaches the vertical line marked "D.C.", that lower part represents the part of the curve corresponding to operation on a weak signal, doesn't it?

A. The very lower end of the curve.

Q. Yes, the very lower end?

A. Yes, sir.

Q. And it is there that in both of these detectors there is a square law action?

A. That is true.

Q. Now, let us go up to the top part of the curve in both cases. Take first the line marked, "Other Detectors". Now, that represents the operation of a triode when the signal has become so great as to—when the signal has reached a certain greatness, doesn't it?

A. I don't think that the curve which is labelled, "Other Detectors" is representative of any use of the triode as a detector, except with very low plate voltages. I think a high plate voltage—with a high plate voltage, the two lines would continue on up together to a considerably higher level before turning over and flattening out.

Q. And the extent to which they continue up together depends in the case of a triode on the height of the plate voltage?

A. That is the major reason.

Q. So that in order to get a stretch in there of straight line of linear response with the triode, you have to raise the plate voltage?

A. Yes, to the desired value.

Q. And simultaneously raise the grid voltage?

A. Yes, sir.

Q. Well, is this a simple way to say it; that this flattening off or overloading of the triode occurs when the signal potential gets up above the biasing grid poten-

tial and consequently brings about a flow of current in the grid circuit of the detector?

A. That is one way that it could happen, and as for the overload or flat part, the top part of the characteristic, the straight part in between of course can be regulated so that for any use for which the straight portion is sufficiently long, what happens beyond that is of no practical consequence.

Q. I guess you will agree, Mr. Kelley, that as these triode detectors were used in radio receiving sets in 1925 and 1926, that is, before the advent of automatic volume control, the signal voltage impressed on the detector was low, and low enough to come down on the square law part of the curve, isn't that right?

A. I think that is generally true in the case of radio.

Q. Before I go to what I had in mind at the moment, I want to check just one thing on this drawing of the Evans system. The grid biasing battery is number 17 there?

A. Pardon me, you are referring to the patent drawing?

Q. Yes.

A. Well, incidentally, the Evans system includes the use of the two-electrode rectifier, if you take the specification in connection with the drawing, so that—

Q. (Interrupting): Now, Mr. Kelley, I did not ask you anything about that. We can handle that proposition of what this generalization in Mr. Evans' specification meant without any assistance volunteered from you.

A. Well, pardon me, Mr. Davis, but I think you referred to it as the Evans system.

Q. I referred to the drawing.

A. I am sorry, then.

Q. This battery 17 is the grid biasing battery, isn't it?

A. Yes, sir.

Q. Now, what we have already agreed on is that when the potential impressed on the grid by the incoming signal exceeds the biasing potential, there will result a flow of current in the grid circuit, and that is one of the causes of this overloading distortion; that is right, isn't it?

A. That is right.

Q. And the potential of the biasing battery 17 must bear a fixed relation to the potential of the plate battery 16; that is right, isn't it?

A. Yes, sir.

Q. So to get any rectilinear characteristic, to get an extended linear portion of the curve of a triode rectifier, you have got to increase both the B battery potential, that is, the battery 16 in Evans, and the C battery potential, or the biasing battery 17 also?

A. That is right.

Q. Now, I understood you to say in your testimony that in that way it is possible to get a triode which will not distort a large signal, but on the contrary will reproduce it with a linear characteristic, is that right?

A. That is right.

Q. Now, do you know when that was ever done? I mean of your own knowledge, do you know of any such thing?

A. No, my memory is not clear on that.

Q. You do not know whether that was ever done as early as this Wheeler invention or not, do you?

A. Well, I could not say because I have no clear recollection; although we used in carrier telegraph system a signal and an adjustment of the voltage which gave us a very substantial linear range on the detector characteristics, which were used for modulated carrier wave telegraph signalling.

Q. You do not know of a radio broadcast receiver that ever used a triode detector that was made linear in that way or any other way?

A. Well, I cannot recall any specific one.

Q. Now, when you look at the Armstrong patent—I mean at the Wheeler patent, beginning in the first column of page 4 at line 62, where he is speaking of the advantages attending the use in connection with his invention of the two-electrode rectifier circuit shown in Figures 1 and 3. He says: "It is impossible to overload this type of rectifier, and the rectified output voltage is directly porportional to the applied alternating signal voltage when this voltage is large, say over two volts. The control system in the circuits of the figures referred to requires a large operating voltage, say 10 volts, so that the latter condition of large signal voltage is realized." Now, you agree, I think, Mr. Kelley, that in this Wheeler system the diode in the circuit which he showed there, that is in series with the high resistance 51, did have a linear response over that range that he is talking about?

A. Yes, sir.

Q. So that you could not overload it, that is, within any such range as he is speaking of here, at any rate?

A. That is right.

Q. Now, he goes on: "No such simple relationship is possible in a three-electrode detector, whose rectified output never exceeds a limiting upper value." As I understand it, you disagree with the assertion that no such relation is possible there, is that right?

A. That is correct. My understanding there is that he is saying that no linear detection is possible for the three-electrode detector. I would agree with him if that implies also that there is no possibility of overloading, but the possibility of overloading is, in a prac-

tical sense, the same if you consider the range over which the detector is to be used. I mean if your three-electrode tube begins to overload at a signal voltage which is beyond what you are going to use, then it is not of any practical consequence that the overloading occurs.

Q. Putting it the other way around, I think what you have in mind is this; that the three-electrode detector would have and will have a linear stretch of the curve, provided it does not overload, or until it overloads?

A. I prefer the second way.

Q. Until it overloads?

A. Until it overloads.

Q. Well, now, won't you agree with me that with the detector they usually used in radio receiving sets at the date that this Wheeler specification was written, the three-electrode, ordinary three-electrode detector that was used as a radio receiver was so constructed and so used in the receiving sets in that day that it would overload with anything like a signal of 10 volts?

A. Well, I wouldn't say that they were not so constructed, because that would not be right. Tubes of that date were constructed so they could be used to—so as not to overload with a signal of 10 volts.

Q. Well, what I mean, I was mistaken in including "constructed", but you agree that as they were installed, with the voltage that was used on the B battery and C battery as of that time, they would be overloaded by a signal anything like 10 volts?

A. Well, the possibility of securing a signal of 10 volts was a remote one in the first place, if you are confining this to radio receivers.

Q. Well, let's bring it down to 2 volts, if it is any easier.

A. Well, I think—

Q. I mean, won't you agree, Mr. Kelley, that with the receivers that were then in use in broadcast radio reception, as they were built and sold on the market, the triode detectors would be overloaded and produce a curve like that shown in Wheeler's figure 4 if they carried any such voltage as he is talking about here?

A. Well, they were adjusted as far as the voltages were concerned, to suit the conditions under which they were used, and since amplification was not easily obtainable at greater frequency which was prior to detection, it would be difficult to secure a large voltage to apply to the detector, so that the question is somewhat academic in my mind.

Q. No, I think your answer to my question is "Yes", with the explanation that there was no need to have a triode at that time that would carry so high a voltage as this. Isn't that fair?

A. Well, pretty nearly. Not in the sense that there was no need for it, but more in the sense that the provision of a sufficiently large signal by the means of amplification was not sufficient.

Q. Well, you brought out in your testimony yesterday that as you expressed it, I think you said that you must have a high signal voltage in order to get on to the part of the curve where there is linear detection?

A. Yes.

Q. And what you are saying now is that, if I understand it, is that there was not then available such amplifying power in these sets to get up to that level?

A. That is in the early days of radio.

Q. Well, I am talking about 1925 and '26, when this specification was written?

A. It was difficult—

Q. (Interrupting): 1927.

A. It would be a difficult thing to get sufficient radio frequency amplification.

Q. Well, you agree that for the amplification then and the size of the signal that was fed into the detector as of that time, this statement of the Wheeler patent is correct, that is, the diode detector would overload—

Mr. Adams: Triode.

Q. (Continuing): —the triode detector would overload.

A. That isn't the right sense to attach to it, however. The voltages were adjusted so that it wouldn't overload for the conditions under which it was used. If the voltage, signal voltage, were large enough, the grid and plate voltages would be properly chosen so that, in turn, it would not overload. That is—

Q. (Interrupting): I understand what you mean, but it is just another way of saying, if I am correct, that at that time, because the signal impressed on the detector was small, the triode detectors had their potentials, the B and C potentials so adjusted that they would have been overloaded by any such signal as Wheeler is talking about here?

A. That is correct.

Q. And another way of saying the same thing is that in order to get Wheeler's intended automatic volume control potential of something like 10 volts out of the signal the amplified signal, he had to amplify the signal to a higher degree than was customary in radio receiving sets at that time?

A. Or that was practicable as well.

Q. Now, you say "practicable", but I say "customary". You will agree with "customary" won't you?

A. And add practicable.

Q. And add practicable. Well, I ask you that question in that form, Mr. Kelley, because I am told that the

evidence stipulated in this case shows that the radio receiver, the broadcast receiver that Mr. Friis made in the laboratory, or in the work of the A. T. & T. in 1924, did have as much amplification of the signal and more than was in Wheeler's set as it is disclosed in his patent, as they had 16 volts, according to the testimony, in the detector. Were you aware of that?

A. I believe I read that in among the depositions.

Q. Well, then, isn't it a little extreme to say that it was impracticable to get such voltages as Mr. Friis got then in his set?

A. Why, I would still say it was impracticable.

Q. Well, it was not impracticable to Mr. Friis, was it?

A. There is a difference between impractical and impossible. It is and was possible. It calls for so many stages of amplification.

Q. Do you know how many stages Mr. Friis had in his set?

A. I don't recall offhand how many stages he had in the set he was supposed to have constructed.

Q. Were you familiar with the R.C.A.'s set number 64, put out in 1929?

A. I don't recall it as such.

Q. Well, if it has been testified in other testimony in this case that that set had sufficient amplification in the detectors, that is, equivalent to Wheeler's, you wouldn't be able to deny that? You don't know anything about it?

A. No, I don't.

Q. You heard Mr. Wheeler's testimony about the Howard detector—well, never mind. Strike that out.

Now, Wheeler goes on in his patent, referring to Figure 4 to say that the linear curve is much more desirable when minimum distortion of a modulated signal is desired.

Will you agree with that?

A. Other things being equal, I do.

Q. Well, now, in this receiver as shown in the drawings of the Evans patent, as I read the drawing, the modulated signal came into this receiver from the wireless system and the whole carrier signal with its modulations was impressed on the grid of the detectors?

A. That is right.

Q. Now, if the detectors had this distortion characteristic, in other words, if it were not so arranged and adjusted as to have a linear characteristic over the range of the signal received, the result in Evans case would be that the modulation on top of the carrier would be distorted in the—would appear in the control potential, I mean, and therefore would tend to wipe out the contrast; that is right, isn't it?

A. If you are referring to the drawing of the Evans patent, and not to the Evans patent as in the full disclosure, there would be, depending entirely upon the adjustment of the grid, the plate voltages and the size of the signal,—if the signal were extremely small, there might be some of this form of distortion, which, by the way, is not a very large factor, and if the signal were any larger there would be less of this distortion.

Q. I want parenthetically here, Mr. Kelley, to ask you some questions about your own relationship to the gentlemen you were working with at A. T. & T. and Western Electric Company. Before I go to the next step in this inquiry that I was going to make, I want to do that. You were employed by the Western Electric Company, as I understand it, from 1920 to 1925?

A. Yes, sir.

Q. And by the American Telephone & Telegraph Company from 1925 to 1929?

A. That is right.

Q. And you were working particularly if I understood your testimony, on systems of communication in which the radio frequency currents modulated according to the signal were put on a wire, and is the system you referred to as wired wireless?

A. That is what I worked on most of the time.

Q. Well, did you know anything about this work that Mr. Evans was doing with the Western Electric Company at that time?

A. I didn't know Mr. Evans.

Q. And you didn't know about the work he was doing on automatic volume control?

A. I don't remember now that I did.

Q. Did you know Mr. Friis who was employed by the Western Electric Company as shown in his patent here in evidence, and who was also working on automatic volume control at about that time?

A. I didn't know him personally. There are about 5,000 engineers in the organization.

Q. You didn't know anything about the work he was doing?

A. Only in a general way.

Q. What do you mean by that?

A. I mean by that that while I didn't know Mr. Friis personally I had a wide acquaintanceship among the engineers and was generally acquainted with the work going on in other departments than my own.

Q. Well, were you acquainted with the work that Mr. Affel had done?

A. Yes. I knew Mr. Affel quite well from 1920 to 1925 and from 1925 to 1929 he was my immediate superior.

Q. Were you acquainted at that time with the system of control that was shown in the Affel patent 1574780?

A. I believe that I was.

Q. In what connection were you familiar with it?

A. Well, in connection with my work on the modulated carrier telephone-telegraph signalling systems.

Q. Did you have any familiarity with it as it applied to radio broadcast receivers?

A. We didn't work on radio broadcast receivers.

Q. You mean either at the Western Electric Company or the A. T. & T. Company?

A. Yes, that is correct.

Q. Among the patents which have been brought to your attention on behalf of the defendant in this case, I note that the following were assigned to the Western Electric Company: The patent to Arnold, the patent to Bjornson, the patent to Friis, the patent to Heising, the two Evans patents and the patent to Schelleng, and those assigned to the American Telephone & Telegraph Company were the patents to Affel, the patent to Perry and the patent to Green. During your work with those two companies did you know of any of that work, excepting the work of Affel that you have testified about?

A. Well, it is difficult for me to say because all of that is at least ten years ago and more than ten years ago, going back practically 20 years.

Q. Now, I want to know a little bit more about your background in the broadcasting field. I understood you to say that in these laboratories you did not work on radio broadcast receiving sets, is that right?

A. It was not part of my job to work on radio broadcast receivers, but the work that we were doing was of, I should say, exactly the same type. In other words, we were working with the same instrumentalities in the same way and for signalling purposes where the same type of modulation was used, and the same functions were performed by the tubes and the tube circuits, and so on, so that when I say I was not working

directly on broadcast receivers, I don't mean to say that I was not working in the art.

Q. Well, no. See if I understand this, that is in this so-called wired wireless the signals are transmitted on a carrier wave of radio frequency, that is, super audible frequency, at any rate, and are modulated just like radio broadcasting?

A. That is correct.

Q. And the receivers have to be equipped with detectors and tube amplifiers just like a broadcast radio receiver?

A. That is right.

Q. But when this question, this problem of blasting that is encountered by the user of a broadcast receiving set, where he is turning his knobs to pick up one station after another, is not encountered in wired wireless, is it?

A. What corresponds to the fading is.

Q. Let us stick to this?

A. Well, I know—

Q. Let us stick to the blasting first. You haven't answered my question about the blasting.

A. Precisely in the form of blasting, no.

Q. That is, in this wired—

A. (Interposing): With one exception, except when there is a radio link in the system.

Q. That is, when the system is receiving radio broadcasting?

A. I didn't say radio broadcasting, but receiving a radio signal.

Q. As I understand it, Mr. Kelley, in these wired wireless systems say a telephone system on wired wireless, and I talk into the telephone. Now, that modulation is put inside of the building somewhere, is put on a carrier, and the volume of it is carefully determined inside the

station. I mean, if I talk too loud into the telephone that is taken care of automatically, isn't it?

A. No, it isn't taken care of that way. I say it is not taken care of automatically. It would produce a louder signal to be modulated.

Q. But the level of energy of voice frequency that goes into the telephone line is very carefully controlled, isn't it?

A. That is correct.

Q. That is to prevent cross-talk?

A. That is one reason.

Q. Now, when that signal gets to the receiving station and I pick up the telephone, or you pick up the telephone at the receiving station to listen in, you just pick up the telephone as you would in any telephone system; you do not do any adjusting of circuits, do you?

A. The person who is listening does not.

Q. And in the receiving station there is a filtering system that has picked out this particular carrier, with its modulations and entirely unknown to the man who is using the telephone, has separated it from all the other things on the wire and has brought it to his telephone?

A. That is right.

Q. Now, did you ever have the responsibility, the responsibility of an engineer for making the choice of a diode detector system and a triode detector system—

A. Yes.

Q. (Continuing): —for automatic volume control in a radio receiving set?

A. No, sir.

Q. That is, you have never been confronted, as an engineer for a manufacture of broadcast receiving sets, with that question, whether you should use one or the other, or whether he should manufacture one or the other?

A. No, sir.

Q. Have you ever had any experience with the manufacture of broadcast radio receiving sets that would enable you to say whether the triode form of a.v.c. gave trouble in the field, that is, lead to the return of defective sets?

A. I would know that from my knowledge and experience.

Q. Well, what is your knowledge and experience?

A. Well, I know the way in which these systems work, and have had the use of radio receivers for my own study. It was an art that was so closely allied to my own work that I was alive to what was going on, and that I understood and would be in a position to know what the problems were and how to solve them.

Q. Well, I am asking a rather specific question, Mr. Kelley. I would judge from the answer that you just gave that you think you are a good enough engineer to predict whether there would be any problems or not, but what I want to know is have you ever been in the practical position where you had to find out from practical experience whether there were objections, objectionable features about a triode a.v.c. system in actual manufacturing practice.

A. Well, I have never been engaged in actual manufacturing practice in connection with the radio receivers, so I think I would have to answer that, "No".

Q. Well, I am told, Mr. Kelley, that in this triode system such as the Evans drawing shows, and if you will refer to that again—I will leave out "I am told", and ask you the question: Is it true that in that system the resistance the plate resistance of the detector, 8, is in series with the resistance, 19, in the plate battery circuit?

A. In that figure, yes, sir.

Q. Now, as I understand it, you have already said,

I think, that if the resistance, the plate resistance of the tube changes, it will affect the flow of current through 19, and consequently affect the biasing or control potential, is that right?

A. Well, that is a secondary way of saying it. The primary way of saying it is that the signal coming in will exercise control over the plate current in an amplified fashion, that is—

Q. (Interrupting): No, I am thinking about another possibility of change of resistance of the tube. As I understand it, in these triodes, the plate resistance of the tube depends upon the characteristics of the tube itself; that is right, isn't it?

A. That is right.

Q. And that depends on the physical structure and the distance between, the physical distance between the elements, and so on?

A. Well, that is perfectly true.

Q. And do you know whether as a consequence of that, if you take out one triode detector from that position and put in another, that had a different internal resistance, you would upset the automatic volume control?

A. If you put a tube in, if you purposely put a tube in of different type, I mean by that different construction, as your question suggests, it would change the adjustment.

Q. I do not know where the "purposely" comes in. I am asking you, suppose you broke the tube in the set, it burned out, and you went and got another and put it in there, and that other one did not have the same internal resistance, what effect would that have?

A. For the reason you say, if it did not have the same internal resistance, is the reason I said if you put one in that was purposely different. If you put one in

that was made to have the same characteristics, then you would not have to make all these readjustments.

Q. Yes, but you will agree that in this triode system, the automatic volume control potential, because of these very things I have been speaking of depends critically upon the characteristic of the tube and the adjustment of the B and C batteries, won't you?

A. Well, critically only in the sense that you should have the correct relation between the batteries.

Q. And correctly related so as to give the correct internal resistance of the tube?

A. Yes, but not critical in the sense that a minute change would make any practical difference.

The Court: I see Mr. Gates is here, if you want him.

Q. (By Mr. Davis): Well, do you know as a practical matter whether or not this variation, as a practical manufacturing matter, whether or not the variation in the triode tubes made it necessary, when the manufacturers in this country did use the triode system of automatic volume control, to make a very careful selection and tests of the particular tubes that they put in there for the triode detectors?

A. That would depend upon who manufactured the tubes. The Western Electric type of tube, which I think would reasonably be used in the circuit of the Evans drawing, were very uniform.

Q. But the manufacturers of radio receiving sets could not buy Western Electric tubes, could they?

A. Yes, they could; I bought them myself.

Q. As a manufacturer ~~of~~ broadcast receiving sets?

A. Not as a manufacturer of broadcasting receiving sets, but as an independent purchaser.

Q. Well, do you know about the Sylvania tubes, for instance?

A. In what respect, sir?

Q. Well, in respect to what we are just talking about, whether you would have to make a careful selection of them in order to make this triode a.v.c. system work?

A. I know that tubes manufactured elsewhere were not as uniform, but it might be that you would have to make some selection if you wanted to be particularly careful about the results.

Q. Well, now, have you any idea as a practical matter what a reasonable value of the resistance 19 would be in the system, if you were going to put it in a broadcast radio receiving set that is shown in the Evans patent drawing.

A. Well, it would be a high resistance and the value of it would be chosen with the end in mind of getting practical operation of the system. It depends on the design.

Q. I was wondering if you could give me a figure, what would be a reasonable amount of resistance there?

A. 100,000 or 200,000 ohms.

Q. Well, now, will you look at the Friis patent—

Mr. Davis: Can we interrupt here and put Mr. Gates on?

The Court: Yes. You can step down. We will excuse you until after recess.

(Witness temporarily excused.)

HOWARD A. GATES, a witness called on behalf of the Defendant, having been previously duly sworn, was recalled, and testified further as follows:

Cross Examination

By Mr. Davis:

Q. Mr. Gates, as I understand it, when you first came with the Detrola Company as an engineer, you were using a name plate containing the numbers of certain patents. That is this Exhibit FF, and then later

you sent in circuit diagrams to the Radio Corporation?

A. That is correct.

Q. And you got a new name plate which is Exhibit GG?

A. Yes.

Q. Did you examine the new name plate to find out what other patents were included?

A. No, I did not examine it. When I wrote to the Radio Corporation of America, I sent them four diagrams which were the most complicated of the receivers we were making, employing more circuits than any other receivers, so that they would cover everything that we were employing at that time, and then we used that plate on all sets in spite of the fact that they did not contain some of the circuits used and marked on the plates.

Q. I want to identify, if I can, the four that you sent, Mr. Gates, and we already have in evidence here a whole set of these drawings?

A. We sent them—

Q. What?

A. —the Models 147, 164, 154 and 137.

Q. Is there any other way to identify those with these numbers?

A. Those numbers have no connection with the receivers that I am now mentioning. These models are known only by their numbers just read.

The Court: I might let the witness find those out during the recess, Mr. Davis. He could probably identify them.

Mr. Davis: I think if I talk with Mr. Gates during the recess, we can stipulate it.

The Court: All right, take a short recess, then.

(Whereupon, a short recess was had.)

Q. (By Mr. Davis): During the recess, Mr. Gates, we found, as I understand it, that the circuit diagrams

that you sent to the R.C.A. that you testified about were later than those that have been furnished to the plaintiff by the defendant?

A. That is right.

Q. Now, did you design a new radio receiving set for Detrola when you became the engineer?

A. Of course.

Q. And you put into it an automatic volume control system?

A. Yes.

Q. And that was a system with a diode and high resistance in series with the diode in the a.v.c. circuit?

A. It was a diode type detector working into a resistance, not necessarily extremely high.

Q. Well, where did you get that circuit from?

A. That was the circuit that I had been using for the previous approximate 5 years for Colonial.

Q. And you didn't get it out of any patent that was owned by R.C.A.?

A. No, I didn't refer to any R.C.A. circuits, because of course I had in mind about the type of receivers that I wanted and had been producing that type before, and simply duplicated with different dials and chassis the same circuits I had been using.

Mr. Davis: That is all. Thank you, Mr. Gates.

Re-Direct Examination

By Mr. Crews:

Q. I have one question on re-direct. I understand your testimony to be you worked for Colonial for 5 years before coming to Detroit?

A. That is right.

Mr. Crews: That is all.

(Witness excused.)

LEO A. KELLEY, was thereupon recalled as a witness on behalf of the Defendant, being previously sworn, testified as follows:

Cross Examination

By Mr. Davis:

Q. I was about to ask you to turn to the Friis patent, if you will. That is patent number 1675848. When you were testifying about that patent yesterday you said that the carrier wave is then amplified and detected in the tube 16. That marks a difference, as I understand it, between the arrangement of Evans and the arrangement of Friis, that is, that Evans amplified the carrier wave plus the modulation, that is, the entire signal and fed it into the detector, whereas Friis handles only the carrier wave, is that right?

A. Well, generally speaking, there is that difference, but as a practical matter, with the use of a single tune circuit as is shown in Figure 1 of the Friis patent, that is, condenser number 13 and coil number 14 taken together, with the fact that it is connected in shunt to the circuit between the boxes 7 and 8 would as a practical matter not select out the carrier wave, but would include the large amplitude, low frequency modulation signals, so that it wouldn't be, from a practical standpoint, there wouldn't be a great deal of difference.

Q. Will you look at the patent, page 2, first column, beginning line 53, where Friis says: "The control current by which the sensitivity of the receiver is regulated is selected from the output of the amplifier-detector 7 by the resonant circuit 13, 14, connected in shunt to its

output circuit, which is tuned to the frequency of the intermediate carrier wave."

Now, what does that mean?

A. It means what I said in my previous answer, which is that the tuning circuit so connected, as a practical matter would not select out the carrier wave only, but would include the lower modulation frequencies, even though the condenser 13 and the inductance 14 were tuned to the carrier frequency, that is, even though they are tuned it doesn't mean that is all that they will pass.

Q. As I understand it, Mr. Kelley, what Mr. Friis said was that he was going to separate the modulation, separate the carrier wave from the modulation and take only the carrier wave into his automatic volume control system. That is what he was proposing to do, isn't it?

A. That is what he says in the specification.

Q. Now, is it your point that the circuit that he shows in the diagram was not adequate to do that?

A. No, my point is that the circuit he has shown is sufficiently selective for his purposes, but that he will include modulation frequencies, nevertheless.

Q. Why did he want to select the carrier and leave the modulation behind, before he used the carrier to produce his control potential, do you know?

A. That would be to prevent any effect that the modulation might have on the amount of rectified current in the detector circuit of tube 29.

Q. That is, Friis was using a triode detector, wasn't he?

A. That is right.

Q. And in order to prevent the modulation from effecting the automatic volume control potential, he separated the modulation from the carrier wave, and

passed only the carrier wave to the automatic volume control system, is that right?

A. Well, his circuit couldn't accomplish that as a practical matter. What I mean is that it wouldn't select out just the carrier wave and no modulation, and as I understand it, since he shows it this way, he must have considered that if only some of the side frequencies were prevented from getting into the detector, then that was sufficient. As a practical matter, he would consider that he had selected the carrier wave out.

Q. Did you have in mind, Mr. Kelley, what Mr. Friis says at the end of his specification, that is, on page 4, beginning with line 69, where he says: "The use of the double detection system," and parenthetically that is what we call the super-heterodyne, isn't it?

A. That is right.

Q. Go on with the question, "however, by establishing an intermediate carrier wave of relatively low frequency, makes it possible to separate the carrier more completely from its accompanying side frequencies and thereby to secure more exact regulation."

Now, isn't Friis saying there that because he has reduced by heterodyning the high frequency of the carrier wave that is received in the set to a lower intermediate frequency that makes his filtering circuit 13-14 effective to separate the lower frequency carrier wave from the modulation?

A. He says that it would be easier to do it under those conditions. At least he says that he could more nearly approach that condition of having only the carrier wave, but you will notice that he uses the language, "more completely", and from the showing on his drawing the use of condenser 13 and inductance 14 is sufficient for his purpose.

Q. All right. Now, his purpose arose out of the fact

that the triode detector that he was using in his automatic volume control system had such a characteristic that if he impressed on the whole signal amplified, that is, the carrier wave plus the modulation, the modulation would in that triode detector give rise to distortion of the amplification control?

A. To some distortion, yes, sir.

Q. And it was to avoid that distortion that exists as the result of the use of the three-electrode detector, that he put in this circuit, 13-14, to separate the modulation from the carrier?

A. No, sir; it was due to the size of the signal which would be detected in the amplifier detector, numbered 7, the box, and he does not indicate what type of detector is in that box.

Q. Yes, but it was nevertheless, that he put in the circuit 13-14 to keep the modulation out of his automatic volume control, didn't he?

A. Yes, sir.

Q. Now, Wheeler and Evans both took into their automatic volume control the entire signal?

A. That is right.

Q. With its modulations?

A. That is right.

Q. But Wheeler, using a diode, in series with a higher resistance, and consequently having a linear characteristic, had no trouble from the modulation affecting the correctness of the control potential, did he?

A. And neither would Evans.

Q. You mean neither would Evans if he used a triode that had a linear characteristic?

A. Or a diode in place of the triode.

Q. Now, listen, Mr. Kelley, I do not agree, you see, that Mr. Evans discloses a diode. I understand your argument, but I do not think it is an argument that is

affected one way or the other by your technical ability, so when I speak of Evans, will you please assume that I am talking about the Evans circuit as it is shown in the patent, with a triode and not a diode?

Mr. Darby: I object to the comment. The witness is not arguing, he is making statements.

The Court: I think the witness is all right, Mr. Davis.

Mr. Davis: All right.

The Court: I do not see—

Mr. Davis: I will withdraw it.

The Court: I do not see how he can answer your question by taking into consideration only a part of the disclosure in the Evans patent. That is, I think it is clearly his duty to take what he considers to be the entire disclosure in the Evans patent. I do not mean by that, that you are not right. I think you can solve the problem by sticking to the drawing, perhaps.

Mr. Davis: To the drawing as it is really my job rather than his.

The Court: Yes. Will you pardon me just a minute, Mr. Davis.

(Short intermission.)

Q. (By Mr. Davis): Mr. Kelley, when you were testifying about this Friis patent, you were asked if you could point out any differences between the Friis circuit and the Wheeler circuit of the patent in suit and you said with regard to the a.v.c. circuit only they are the same. Now, I want to get you to follow this circuit of the Friis patent by means of which he gets his automatic volume control. As I understand it, we start at that point where the circuit branches off between the Figures 7 and 8 on Figure 1 of the drawing. Now, that circuit, as I understand it, takes the entire signal, including its modulation, and the filter, 13 and 14, is sup-

posed to remove the modulation and leave it behind. I am right so far?

A. Yes, sir.

Q. You say you think it would not remove it all, but it would remove some of it?

A. Yes, sir.

Q. Then the carrier current with whatever part of the modulation was not removed, if any, passes on, as I understand it, to the tube, 15, which is an amplifier; is that right?

A. That is right.

Q. Now, Wheeler hasn't any such amplifier as that in his automatic volume control circuit, has he?

A. No, sir. What I had in mind in answering that question was not this portion of the Friis circuit. What I had in mind was that the signal was rectified, and I was not indicating in what way the signal was rectified, whether by a diode or whether by a triode, but that rectified current from some source was caused to flow through a high resistance and that the voltage developed across that high resistance was applied to the grids of the controlled amplifier in conjunction with a condenser which is here 22, to provide, with the resistance 18, the proper time constant. It was in that sense that I answered that question.

Q. That is, in that sense, that you said that the two a.v.c. circuits were the same?

A. I understood the question to be to restrict myself to the control circuits.

Q. Well, all right. Now, what I am trying to do is to show how Friis differs from Wheeler in the instrumentalities that he actually put into the set to get automatic volume control, and I understand you agree that Friis in the first place put in this filter circuit, 13-14, which Wheeler does not have, and that he also put in the amplifier 15, which Wheeler does not have?

A. Yes, sir. I think that in my testimony I explained in connection with the Friis patent that these two extra tubes were added.

Q. The other extra tube being the detector tube 16?

A. That is right.

Q. Now, that detector tube 16, like the detector tube in the Evans patent, is a triode detector?

A. As shown in the drawing of the Evans patent it is.

Q. And it has, like the drawing of the Evans patent, a plate battery, which is 17 in Friis and 16 in Evans; that is right, isn't it?

A. That is right.

Q. And the resistance 18 of Friis corresponds to the resistance 19 of Evans?

A. Yes, sir.

Q. And the condenser 20 of Friis corresponds to the condenser 22 of Evans; is that right?

A. No, sir. There is a simplification in the Friis arrangement of the resistance and condenser time constant, as there was when I mentioned—pointed it out in Affel, in that the direct current for control alone is developed in the resistance 18 of Friis. That is, there is no audio-frequency developed in the resistance 18 of Friis, and that—

Q. (Interrupting): Let me interrupt you there. That is because the modulation has not been permitted to get to the detector; isn't it?

A. That is right, and that this—that is not entirely the reason. That is, it happens to be the reason in the case of Friis, but not the reason in the case of Affel.

Q. In the case of what?

A. The reason is that the output of the detector which is used for control in Friis as in Affel, was for the purpose—

Q. You are talking about Affel?

A. Pardon?

Q. How did we get Affel?

A. I was comparing the resistance-condenser combination in Friis with the resistance-condenser combination in Affel for illustration.

Q. All right, go ahead. Maybe you finished?

A. Well, that there is only one time constant ~~circuit~~ necessary and it performs a double purpose in Friis.

Q. Then it is true of this Friis arrangement, as it is of the Evans arrangement, that the control potential is not derived directly from the signal itself, but is derived indirectly from the B battery of the triode detector tube, isn't it?

A. Well, in the drawing of the Evans patent, the energy, the source of energy, is the plate battery, but the thing that does the work is the signal that is amplified in the tube.

Q. You mean the thing that does the controlling?

A. The battery is a static thing, the plate battery is a static thing. It has a certain voltage and it merely energized the plate circuit. The things that take place are as a result of the incoming signal.

Q. Well, what I am trying to get at is much simpler than that. I just asked you if it is true of Friis, as you admitted it was true this morning of Evans, that the signal—the control potential is not derived directly from the signal itself, but is produced by energy from the battery controlled by the signal? I mean in that respect the two are the same, Evans and Friis? 1

A. Well, the Evans drawing and the Friis drawing are alike in that respect.

Q. Yesterday you were testifying about the screen grid tube, and its relation to the triode amplifier that preceded it. That is, as I understand it, the triode amplifier that was used in the ordinary broadcast receiving

set was replaced about 1929 or thereabouts with this screen grid tube brought out by the Radio Corporation; that is right, isn't it, so far?

A. Yes, sir.

Q. Now, until the advent of the screen grid, these radio frequency sets,—I mean immediately before the advent of the screen grid, the standard broadcast radio receiving sets were the so-called Hazeltine Neutrodyne sets, were they not?

A. Well, some of them were the Hazeltine Neutrodyne. There were others that used different methods of neutralization, but if you mean tuned radio frequency using the triode and some form of neutralization, the answer is "Yes".

Q. That is the standard sets of that time which were tuned radio frequency type, had to have some form of neutralization to prevent energy being fed back through the tube itself and giving rise to oscillations inside of the set; is that a fair statement?

A. Well, that would be an extreme case of trouble. It was even to prevent—to prevent sufficiently large amounts of feed-back to distort the signal even before oscillations would take place.

Q. And the feed-back path that was neutralized in these sets was the path through the tube itself; wasn't it?

A. Yes, sir, from the grid to the—

Q. (Interrupting): And when the screen grid came along, the screen shut off that path, so it was no longer necessary to neutralize it. That is substantially correct, isn't it?

A. Yes, sir.

Q. And after that the neutralized sets were replaced by sets which used screen grid tubes and therefore did not need to be neutralized. Is that fair?

A. It was more than that. Not only did the screen

grid tube do away with the necessity for neutralizing, but the screen grid tube also provided a much greater amplification than could be obtained with the triode.

Q. Well, then, coming to that matter of the relative amplifying power of the screen grid tubes, and the triodes, you said yesterday that—or the other day, on page 227 of the record, it is, that the mutual conductance of the tube—I am quoting now—"which is often called a figure of merit for this reason, that it indicates how useful the tubes can be in the way of amplification, the mutual conductance or figure of merit is more than doubled over the triode." That is, you were saying, as I understood it, that the figure of merit, the mutual conductance, and I understood you to mean the amplifying power of the screen grid tube, was more than double that of the triode.

A. That is not what is meant there. That mutual conductance is one of the factors involved in amplification, and I was enumerating that with other factors to indicate the enormous increase in the amplifying ability of the screen grid tube over the triode.

Q. Well, now, as a matter of fact, the mutual conductance of triodes in 1929 was just as great as the mutual conductance of the screen grid tubes of that time, and the mutual conductance of the triode of today is just as great as the mutual conductance of the screen grid tube of today; isn't that right?

A. I was indicating, if—that is correct. You just showed it to me during the recess in our manual of that year, 1929, but what I had in mind in my answer, when I said triode, I had the 201A tube, which Mr. Wheeler refers to in his patent specifications, and I wanted to indicate the improvement in that particular respect of all tubes, and that, as I say, is only one factor, so that actually it is possible to get four or five or even

more times as much amplification per stage regardless of this figure of merit or mutual conductance, with the screen grid tube than it is with a triode.

Q. Well, according to this bulletin of the R.C.A. Radiotron, the 201A had a mutual conductance, the figure is given here in the bulletin of 800, is that right?

A. It gives two figures, one 725 and the other 800, depending upon whether 90 volts or 135 volts is used upon the plate circuit.

Q. Well, now, I direct your attention to this bulletin where it is referring to tube number 224 under date of 1929, and that is a screen grid tube and that gives mutual conductance figures of 1,000 at 180 volts and 1,025 at 250 volts, is that right?

A. That is right.

Q. Now, I direct your attention to a similar showing with respect to the R.C.A. Radiotron number 227 which is a contemporary triode and the mutual conductance is given at 90 volts, 820, at 135 volts 1,000, and at 180 volts 1,000, 250 volts 975, is that right?

A. Yes, sir.

Q. Now, coming up to the present time with these bulletins, I have the R.C.A. bulletin showing the R.C.A. 6-C-5 detector amplifier triode and the mutual conductance, now referred to as the transconductance, is given at 2,000 at 250 volts, is that right?

A. Yes, sir.

Q. And a screen grid tube contemporaneous with that R.C.A. 6D6, is given as a transconductance of 1,500 at 100 volts, at 1,600 at 250 volts?

A. Yes, sir.

Q. So that would indicate as a matter of fact, the diodes without the screen grid have just as high mutual conductance—the triodes without the screen grid have just as high mutual conductance—perhaps a little higher than the screen grid tubes?

A. No. It would indicate, as you started to say, that of the present day, the triodes and screen grid tubes are comparable in the mutual conductance, but it doesn't mean that the triode mutual conductance is higher, because we only looked at selected tubes, but there has been and I think our reference to the manual indicates it, exactly what I had in mind, was the rise from 700 to 800 for mutual conductance to values of 2,000 in present day tubes.

Q. Yes, but, Mr. Kelley, at this critical period, 1929, when the screen grid tubes were used and when automatic volume control came into use, the bulletin shows, does it not, that the triodes of that year had just as high mutual conductance as the screen grid tubes of that year?

A. Yes, but the amplifying power of the screen grid tube was far in excess of that of the triode, and that is what I was trying to state in my answer. My reference to mutual conductance was a reference to one of the factors, not the main factor, or the only factor.

The Court: What does mutual conductance mean?

A. It is a technical term applied to a certain type of measurement that is made on the tube with a certain voltage applied to the input of the tube, rather a certain change of voltage applied to the input of the tube, will cause a certain change of current in the plate circuit, and it is the ability of the tube to produce a given range of current flow in the plate circuit as compared to the voltage which is on the input circuit, and that the ability of a tube to utilize its mutual conductance depends upon the type of circuit that can be connected in the plate to utilize that current, because the higher the impedence you can cause that current to flow through, the higher the voltage you can generate in your coupling circuit, and the amplifying ability of tubes that we are speaking of depends upon the voltage ratio between what

was applied on the input as compared with what is developed in the output and reaches the input of the next tube, so that there is a conversion from current to voltage after applying the mutual conductance factor and the reason, or one of the main reasons why the screen grid tube is so superior is that its own plate impedence is so large that a very large impedence can be used in its plate circuit, thereby developing a very high voltage.

Q. Mr. Kelley, in your testimony on direct, I think perhaps merely by coincidence, and that is what I want to straighten out; you read from Major Armstrong's patent number 1716593 at a point where he said, I am quoting, "Extremely high amplification is necessary to produce an electromotive force of one or two volts across the detectors and resistances, and for this purpose six to ten stages of vacuum tube amplification may be necessary."

Then in the next question you were asked, "And until the screen grid type of tube amplifier became available on the market, what was the only expedient available to obtain the large amount of voltage necessary to be able to use a diode type of rectifier," and your answer was: "It would be necessary under those circumstances to use a large number of stages, that is vacuum stages of amplifiers of the three electrode type in order to obtain a sufficiently large output voltage."

Now, I am assuming that you had no intention of connecting those statements together, that is, you weren't using the expression. "A large number of stages" as corresponding to the 6 to 10 stages that Armstrong mentioned?

A. It was a coincidence, Mr. Davis.

Q. What did you have in mind when you say in the absence of screen grid tubes, "It would be necessary to

use a large number of stages." How many stages did you mean?

A. I meant that you would have to secure amplification by using a larger number of stages, because with the screen grid tube you get more amplification in one stage.

Q. And how many larger, I mean; you use three stages instead of two, or 10 stages instead of 2?

A. I think that the best answer to that is the Howard receiver, for example, that Mr. Wheeler testified about, and the number of tubes that it employed before rectification.

Q. Well, that had four instead of three?

A. Pardon me.

Q. You mean the Howard receiver had four tubes where the ordinary receiver, without the automatic volume control would have three?

A. I do not recall how many that is said to precede the detector, but I do recall that the number of tubes altogether for amplification purposes was nine.

Q. Well, isn't this the simple fact of the matter, Mr. Kelley, that at the time when Wheeler's a.v.c. was invented, the ordinary radio frequency broadcast receiver did not raise the potential of the signal high enough for his purpose, so that he had to put in additional amplification before the detector, in order to get a strength of amplified signal sufficient for detection in the diode arrangement, that he had patented?

A. Yes, and that would be the extra stages.

The Court: All right, Mr. Davis. We will quit for tonight. Nine o'clock tomorrow morning.

(Thereupon, an adjournment was taken until the next day, Wednesday, November 1, 1939, at 9:00 o'clock A. M.)

Detroit, Michigan,
Wednesday, November 1, 1939,
9:30 o'clock A. M.

Court met pursuant to adjournment.

LEO A. KELLEY, was thereupon recalled as a witness on behalf of the Defendant, being previously duly sworn, testified further as follows:

Cross Examination (Continued)

By Mr. Davis:

Q. Mr. Kelley, I want this morning, if I can, to clarify somewhat with you this matter of the use of a resistance in series with the detector in an automatic volume control system. You said the other day that, in answer to a question of Mr. Darby's, that the use of a resistance is universal in all types of automatic amplification control to develop the voltage necessary to control the amplification, and it has appeared from the patents that we have already discussed, that both with the triode detector and also with the diode, there is a resistance in series in the automatic volume control circuit, is that right?

A. Yes, sir.

Q. And it appeared yesterday from our discussion that sometimes these detectors, whether triodes or diodes, will have a linear characteristic, and sometimes they will not, depending upon something in the circuit, some arrangement of the circuit, that is right, isn't it?

A. Yes, sir; and the use of the instrumentality, I mean with respect to the size of the signals applied to it.

Q. Yes. We understood that in both cases, that is,

both the triode and the diode, you would not get the linear rectification unless you had a relatively large signal?

A. Yes, sir.

Q. Well, now, since the use of a resistance is universal in these circuits and the linear characteristic is not universal, I conclude that the mere use of resistance is not enough to make the circuit linear, to make the response linear, and what I want to get is what is it about the resistance, what kind of resistance must you have in order to make the response a linear response?

A. Well, you should have a resistance which is reasonably large and for the purpose of controlling the amplification by means of current flowing through this resistance you would naturally select a large resistance in any case.

Q. Well, now, I would like to get some relative standards of this relatively large. Large with relation to what?

A. Well, it would be large with respect to the impedence of the tube itself, or at least comparable with it.

Q. Well, that is the largeness or smallness when we speak in this discussion of a large resistance, it has relation to the, or comparison to the resistance of the tube itself?

A. I think generally speaking it does, although I find no definition of that sort in any of the patents that we have been discussing.

Q. Well, as I understand it, the nature of the current, the amount of the current that flows in the circuit which contains in series a resistance and a tube, detector or rectifier, depends upon the resistance within the tube and also upon the external resistance put into the circuit; that is, upon the sum of those two, doesn't it?

A. Yes, sir, if that is all there is in the circuit.

Q. Yes. Now, just confining—I think it is sound enough

to confine our discussion as to the effect of the resistance to that assumption, isn't it?

A. Yes, sir.

Q. And, as I understand it, in order to get this linear reaction you want to subordinate the effect of the tube resistance and exaggerate the effect of the external resistance, because the external resistance is a permanent and fixed resistance, and the internal resistance of the tube varies; isn't that right?

A. To the extent that the resistance is made higher in value the characteristic of that circuit is more nearly uniform.

Q. So that, to get a good linear response, what you really want is an external resistance that is high with relation to the internal resistance of the tube?

A. If you want to get anything approaching perfection you would make it high. That is, it doesn't follow that if it is not extremely high with respect to the internal resistance of the tube, that you will not then get a reasonably linear characteristic if you use a large signal. But, if you are striving for something extra you may use a still larger resistance.

Q. Well, isn't it—

The Court: (Interposing): Wait a minute, Mr. Davis. Will you read that answer?

(Last answer was thereupon read by the reporter.)

Q. Well, isn't it very much like a big man who wants to go straight, and a little boy who wants to go crooked, and the bigger and more powerful the man is, the more likely they are to go straight; isn't that a pretty good illustration?

A. Well, I don't know as I quite get your analogy.

Q. Well, I mean the external resistance tends to make the result uniform and desirable; to make it of a desirable character?

A. There is no question about the external resistance helping to attain this linear characteristic.

Q. And, in the Wheeler patent, I think we have already brought out that the value of the external resistance mentioned in the patent was one million ohms, and that the internal resistance of the diode, you said, was somewhere in the neighborhood of 5,000 ohms; is that right?

A. Well, I don't know what the internal resistance of his diode was. You asked me to select a figure for some other purpose, and I said 5,000. I also explained that it isn't a definite or uniform value, but for the purpose of that discussion I selected 5,000 ohms, explaining that if the current flows in one direction it is practically infinite as far as resistance or impedence is concerned, and in the other direction, depending upon how far positive the voltage goes, the value of the resistance through the tube also varies, and I selected some value, as I say, for the purpose of discussion.

Q. Well, for the purpose of giving just an order of magnitude rather than a particular value, isn't that right?

A. That is about right.

Q. Now, as I understand it, the internal resistance of the triode tubes is of a somewhat higher level than the diode tubes. Can you give me an average figure for the internal resistance of the triodes?

A. Well, the triode tubes with which I am familiar varied all the way from about 2,000 ohms up to 30,000 ohms.

Q. I suppose you are talking—well, I suppose you are thinking of the tubes of the Western Electric Company, probably, aren't you?

A. The Western Electric Company, and the common types of triodes that have been used in radio receiving sets.

Q. I think you will agree, or perhaps we did agree yesterday, at any rate I will ask you again, with reference to the patent to Friis; I think it was brought out, that is tab 11, your Honor—that the resistance 18 of Friis corresponded to the resistance 19 of Evans' drawing, is that right?

A. Yes, sir.

Q. And when I asked you yesterday about what you thought would be a reasonable value for the resistance 19 of Evans, or maybe I asked you about the resistance 18 of Friis, I do not remember now, but at any rate you gave a value of 100,000 ohms. I call your attention to the fact that Mr. Friis testified about building a set for the Western Electric Company embodying this circuit of his patent and when asked what the actual resistance of that external resistance was, he said around 20,000 ohms. I am referring to page 677 of the testimony of Friis. Would that testimony cause you to make any other estimate or to modify your 100,000 ohm estimate?

A. No, sir, because that testimony merely indicates what one individual used in a particular case.

Q. Mr. Friis also testified in that case that the resistance of the diode that he was using, of the triode, rather, that he was using, was in the neighborhood of 30,000 ohms. That would not be out of accord with your knowledge of the internal resistance of the triodes used at that time by the Western Electric Company, would it?

A. That would be at the extremely upper end of the impedences of the tubes with which I was familiar.

Q. I show you a photograph of a triode tube of the Western Electric type. Is that like the tubes that you used when you were with the Western Electric Company?

A. In outward appearance it looks the same.

Q. And that is the tube that was used by Mr. Friis in his set, and it is marked with a resistance of 52,000 ohms. Have you any reason to believe that tubes of the Western

Electric Company at that time, when used as a detector, the three-electrode tubes, did not have a resistance as high as 52,000 ohms?

A. It depends entirely on what tubes were used. The Western Electric Company manufactured quite a number of different types of tubes, having different characteristics, and generally looking the same to all outward appearances.

Q. Well, you will agree with me, I think, Mr. Kelley, that if Mr. Evans in his circuit, or Mr. Friis in his circuit, used an external resistance of a value of approximately 20,000 ohms, with a tube that had an internal resistance of say 20,000 ohms, they would not get a linear response?

A. They would get an approximately linear response, however.

Q. What would they have to do to get a truly linear response?

A. You never get a truly linear response; it is a matter of degree. As you increase the resistance you take more of the kinks out of the characteristic, and that was a well-known thing; as far as my own experience is concerned in this art, from 1920 on, that the size of a resistance connected in series with a device having a non-linear characteristic made the characteristic more linear.

Q. And that is the—

A. (Interrupting): That is a general principle.

Q. (Continuing): That is the subject matter of the Armstrong patent that you directed our attention to, isn't it, that is the way he got the linearity?

A. He points that out, yes, sir.

Q. Now, the defendant in this case puts in series with its diode 550,000 ohms, doesn't it;

A. Yes, sir.

Q. And if you are going to put anything like that

resistance in series with the triode you would have to correspondingly increase the B battery voltage and the C battery voltage, would you not?

A. Yes, you would have to select the correct voltages.

Q. That is a point, with respect to the diode, I wanted to bring out yesterday, and did not. I will tackle it now. As I understand it, that when the triode was used as a detector in the ordinary radio receiving sets, I am speaking of a period prior to automatic volume control, the direct current characteristic, or direct current component, rather, of the output, was not utilized?

A. No, sir, that is for radio reception.

Q. That is, you mean, no, it was not utilized?

A. It was not utilized for radio reception. There were cases in which it was utilized.

Q. I take it that you have in mind perhaps the same thing you had in mind yesterday when you said you had used the diodes as rectifiers, when I asked if you had used them as detectors. I think we ought to explain that a little. As I understand it, the diodes were used commercially for power rectifiers, is that right?

A. Yes, sir.

Q. And that is what you had in mind when you said that with the Western Electric Company, you had used them as rectifiers?

A. Yes, sir.

Q. And I do not think you disagree with the testimony that has been given, do you, that the diodes, as a detector in radio reception, had been in the years from the war to 1923, say, had been superseded by the more sensitive triode detectors in actual practice?

A. I do not know that it was superseded although the greater amplifying powers of the three-electrode tube made it more popular.

Q. When you heard Mr. Wheeler testify that when he wanted to use a diode in his set, he couldn't get it, that

is, there wasn't available to him a diode tube suitable for radio purposes, so he took the available triode and connected the grid and plate together to make a diode out of it; you heard that testimony?

A. Yes, sir; and I have done the same thing myself in the very early 20's.

Q. I brought out that for automatic volume control you make use of the direct current component of the energy in the output circuit of a triode, which was not used for detection purposes, and I want to ask you now upon what does the strength of that direct current component in the output circuit of a triode depend?

A. It depends upon the amplified strength of the incoming signal, together with the potentials used for energizing the tube. That is the plate and grid battery.

Q. And also depends upon the internal characteristics of the tube, doesn't it? I think we brought that out yesterday.

A. Well, that is necessarily included.

Q. Now, having regard to the fact that in Defendant's set the diode is used with over half a million ohms of resistance, do you think it is correct to say that in the Defendant's set the operation of the diode is made independent, or substantially independent, of the internal characteristics of the tube?

A. I think that would be correct.

Q. Now, I want to direct your attention for a moment to the use of the so-called Fleming valves, which I understood to be a diode, as detectors before the advent of the three-electrode detectors. I think you will agree at that time the signal voltage received in a radio receiving set was relatively low?

A. At that time, meaning, say before 1920?

Q. Yes.

A. Yes, sir.

Q. And this incoming signal voltage was rectified by

the Fleming valve or diode detector and passed on into the telephone circuits, wasn't it?

A. Into a telephone receiver wound to a high impedence.

Q. And it was the current produced by this signal passing through the coils of the telephone receiver that constituted the voice currents in the telephone and gave rise to the telephone sound, wasn't it?

A. Yes.

Q. In other words, the output of the diode in that use was used in the form of current, electric current, to produce a sound in the telephone?

A. Generally speaking, yes, but I do want to include that there were many different types of circuits. That is, you can't refer to one circuit only, but I think your description would apply to a common type of circuit.

Q. Have you in mind any figure that you can give for the value of the resistance of that of what you refer to as the telephone wound for high impedence?

A. I was trying to recall the value of the impedence. It is not merely the direct current resistance, but also the impedence to the voice currents which actuate the telephone receivers which must be considered.

Q. Let me make—

A. (Interrupting): It would be in excess of ten thousand ohms.

Q. Perhaps I can put in here, Mr. Kelley, to make it perhaps plainer, what you just said, that when you speak of the impedance to the varying current as distinguished from the resistance to the direct current, in that case do you have in mind the fact that a coil of wire offers more impedance to the flow of a varying current than it offers resistance to the flow of a direct current, is that right?

A. That is correct, and there is also an increase—well, in the present discussion this wouldn't apply, so I won't go on with it.

Q. I wonder, and I am asking you, Mr. Kelley, in view of what has been said here already, in what sense you said to Mr. Darby that in 1923 the best-known type of vacuum tube rectifiers were the two-electrode type?

A. Is that your question, sir?

Q. Yes.

A. I meant that in the sense that the two-electrode type of rectifier, the Fleming valve, preceded in point of time the three-electrode type of tube, and that it was very well known concurrently with the three-electrode type of tube and being longer known was better known.

Q. Now, will you look with me for a minute at this patent to Affel? That is tab number 8, I think, in your book?

Mr. Darby: Tab number 8, right.

Q. And you brought out in your testimony about it the other day that in that patent the energy which is used to produce the automatic volume controlling potential was taken off of the system before the amplification, that is right, isn't it?

A. Yes, sir; I pointed that out.

Q. And you said in answer to a question of Mr. Darby's that insofar as amplification control is concerned, it does not make any difference whether the voltage for automatic control is obtained before or after it goes through the amplifier. That was his question. And you went on to say, in the end result there is no substantial difference, and that is indicated in a curve shown in Fig. 5 of this Affel patent which represents the end result. Now, the curve of Fig. 5, as I understand it, corresponds to the curve in Wheeler's patent in suit of Fig. 2?

A. Yes, sir.

Q. And, so, the effect of your answer was merely to say that both of these systems result in automatic volume control, wasn't it?

A. Precisely.

Q. Now, actually, isn't it true, Mr. Kelley, that since, for this type of automatic volume control that is being discussed in this court now, we have agreed that you must have a high initial voltage fed to the rectifier, doesn't it follow from that, that in that sense it does make a good deal of difference whether you amplify the energy before you feed it to the a.v.c. circuit or not?

A. It doesn't make any difference in my answer, Mr. Davis.

Q. No. But, it makes a lot of difference in whether you get in these receiving sets, whether you get rectilinear response; that is, a control potential proportional to the signal, it makes a lot of difference whether you amplify the signal before or not, doesn't it?

A. It makes a lot of difference whether the signal is large enough, if you wish to get linear rectification.

Q. And, you can't get a signal out of the atmosphere that is large enough to get linear rectification without amplification, can you?

A. Generally speaking, no, but in Figure 1 of Affel, there is no indication of what may be connected to the left-hand terminals of the figure; that is the two terminals designated by the two very small circles. That may have come from an amplifier, and the size of that signal coming in, you simply don't know whether it is large or small.

Q. Well there is no indication in the Affel patent that he had in mind the application of his plan to broadcast radio receivers?

A. It certainly did include a broadcast receiver.

Q. But, actually Mr. Affel was working with the telephone company and he did attempt to apply his automatic volume control system to the telephone circuits, didn't he?

A. I think he did.

Q. Well, you worked there with him, didn't you?

A. Yes, sir.

Q. And, don't you know that he did attempt to apply his automatic volume control system to telephone circuits?

A. I think that he did. I don't recall clearly.

Q. Well, do you know, Mr. Kelley, what type of control, that is, which one of his patents, if any, represents the type of automatic volume control that he tried to apply to the telephone circuits?

A. I don't remember, Mr. Davis, but I wish to point out in the specification that his language very clearly includes the use of his circuit in radio systems.

Q. I quite agree with that, Mr. Kelley. I don't think we disagree on that. If I understand what you mean, the language of the disclosure of the Affel patent is in general terms so as to be generally applicable to systems carrying radio frequency or super-audible frequency carrier waves in the circuit, isn't that right?

A. Yes. And, it was well known to me at the time that I was with Mr. Affel that the technique, the instrumentalities, and so on, of the carrier wave art, was precisely the same as that of the radio art. They utilized the same things; they did things the same way; they borrowed from each other.

Q. The point I was bringing out was that after all if you took the showing of the Affel patent and attempted to apply it to a radio frequency broadcast receiver, you would, to get any practical result, you would have to do as Evans did, that is, put the amplifier before, ahead of the rectifier, instead of doing the way Affel did in this picture, put the rectifier ahead of the amplifier?

A. Well, there is no clear indication in Affel whether amplification might not have been included—

Q. (Interposing): I understand that.

A. (Continuing): —in the circuit connection to the left.

Q. But, in the drawing itself it does show an amplifier and shows the energy taken off before it is amplified; you agree with that?

A. It is taken off before it is amplified by the tube AT, but what I am speaking of is what other amplification may have preceded it.

Q. Well, you will agree with me, I guess, that if you are going to apply such a system of automatic volume control to a radio receiver, you would have to do as Evans did in his wired wireless system, that is put the amplifier ahead of the detector, whether Affel did it or not?

A. You should have amplification before—you should have a sufficiently large signal; that is the point.

Q. Well, am I mistaken, Mr. Kelley, in supposing from your testimony on direct that you pick out the Evans patent as being the closest approximation in its disclosure, to the Wheeler invention?

A. I pick out the Evans patent as being the best reference with respect to the Wheeler patent.

Q. I want to turn now, if you will, to these patents that you referred to which show the use of diodes, and I think we pretty well covered the Armstrong patent except that I will ask you this; it is true, isn't it, that Armstrong was using the output of the diode, he was using the current rather than the potential to operate his peculiar system of reception?

A. That is an ambiguous statement, because he derives the energy which he intends to utilize from the detector by means of a transformer, and the transformer that he happens to show, he gives no values for its impedence, but a transformer is equivalent to the, whatever the load impedence on the output circuit of the transformer may be, and in this case, that is in Arm-

strong's case, that load is an energy-absorbing device; that is, its effect is that of resistance. And, the resistance would constitute the load in that particular place. But, aside from that, the use of transformers and potentiometer type, that is the resistance capacity types of coupling, were well known and were interchangeable depending upon which you found more suitable to use.

Q. Well, will you agree with this, that the Armstrong patent discloses a special system intended to prevent or to shut out static, and his use of a diode and resistance to give linear detection was not a use in connection with automatic volume control?

A. Oh, yes, I will agree to that.

Q. Now, turn to the Slepian patent, will you, please? Now, Slepian, in this patent, says that his purpose is to provide a receiving system which admits of extremely high amplification of received signal impulses. I am reading lines 20 and following, of page 1. This device, or, this patent, discloses a form of what was known as a super-regenerative receiver, doesn't it?

A. It is a special type of receiver working on the super-regenerative principle.

Q. And that super-regenerative principle was invented by Major Armstrong and was subject to a good deal of discussion around the early 20's, wasn't it?

A. I think so.

Q. In the super-regenerative system, as disclosed in the Slepian patent, as I understand it, Mr. Kelley, the high amplification is attained by making use of this regenerative feed-back which brings about oscillations, and which you have said in your testimony must be excluded from the tuned radio frequency receivers such as they use in broadcast reception, or such as the automatic volume control was applied to by Wheeler and by the defendant, is that right?

A. That is to present—yes, that is right, that is right.

Q. That is, the super-regenerative circuit makes use of that regenerative feed-back which causes oscillations?

A. Which tends to cause oscillation.

Q. And the way that works, as I understand it, is that by feeding back energy from the output circuit of the amplifier tube shown in Figure 1 and bearing a numeral "1", I think, by feeding energy back from the output circuit of that tube to the input circuit of the tube, he releases into the circuit a large amount of energy from the B battery of that tube, is that right?

A. Yes, sir.

Q. And the idea of the patent is that the incoming signal will so affect the circuit,—I will come back later to how that is done,—but, will so affect the circuit as to cause this feed-back of energy to start the tube into oscillations, and then when the signal stops the damping of the circuit will cause the oscillations to stop, is that right?

A. No, sir.

Q. Well, what is the trouble with it? Have I used the word "oscillations" when I should have used some other word?

A. No, sir, you said when the signal stopped, they would die down, and that is not correct.

Q. Well, as I understand it, these waves of energy, whether you call them oscillations or impulses, are intermittent; the patent calls them "intermittent impulses".

A. That is not the signal, sir.

Q. Oh, I understand it isn't the signal, that is what the signal releases from the B battery into the circuit, is a series of intermittent impulses, isn't it?

A. A series of intermittent impulses, whether there is a signal or not, that is before the connection of the controlling device, and that is where the control comes from,

namely the diode circuit which is coupled to the output of that amplifier.

Q. Well, perhaps we are not in disagreement. I do not know. I will go a little further and find out. My understanding is that in that system these intermittent impulses, their energy is fed to the detector, that is, to the diode detector and is rectified there, and the rectified current produces a potential across the resistance, 9, and that potential is applied to the grid of the tube, 1, is that right?

A. No, sir, you have not described the operation of the circuit correctly.

Q. Well, will you describe it correctly?

A. Yes, sir. During the reception of signals, that is, coming in from the antennae, 23, the energy from the antennae is fed through the coil 25, to the coil 7, at the particular instant depending upon whether the oscillations in the amplifier tube circuit are about to start or not, there will be set up at the instantaneous value of the incoming signal a train of oscillations that would build up.

Q. That is what he refers to as the intermittent oscillations?

A. No, it is not. That train of oscillations then starts to build up, and as it does so, the energy fed back from the output circuit of the amplifier tube, 1, from the coil, 15, to the coil, 16, introduces energy into the diode circuit, the two-element rectifier circuit, whereby the train of oscillations building up is controlled, so that at any particular time that this happens, the build-up of oscillations, the maximum value of which it reaches, will correspond to the instantaneous value of the signal coming in at that time, so that when this is happening over and over and over again there results, as one of the products of the process in the telephone receiver, 11, a reproduc-

tion in amplified form, of the modulation signal, that is the audio-frequency or speech or music, whatever it may be. In other words, the diode circuit controls the amplification possibilities of the tube, 1.

Q. Well, now, you have spoken of the building up of these impulses, but I didn't hear you say anything about the fact which is mentioned in the patent, that because of the grid leak and its adjustment, there is an intermittent discharge of the grid potential and consequently these trains of oscillations are forming into an intermittent series of energy impulses. That is the way it works, isn't it?

A. I don't think your language is quite exact. What I said that happens over and over again, is the thing that starts with the beginning of each one of these intermittent starting periods which he refers to as intermittent oscillations. That is, I think you were looking at the passage that I am, that is, page 1, line 92. He is describing what will happen if you don't have his control circuit on there. In other words if you didn't have the diode circuit on and your set adjusted to amplify with its feed-back and the condenser 9 and 8 being there, you would get intermittent pulsations, but now he adds to the circuit an amplification control circuit, including the diode so as to control the signal.

Q. Control of it, now, stick to it, to control the amplitude of the intermittent pulsations?

A No, the signal coming in controls that.

Q. Yes, through the grid?

A. The signal coming in determines the particular instant when these oscillations start to build up, determines how high they will build up under the control of the diode circuit.

Q. Well, I think we agree on that. That is, these intermittent oscillations are brought about in the manner

which Slepian describes, and the amplitude is controlled by the signal in the way that you have described?

A. Precisely.

Q. And it is the intermittent oscillations that are heard in the telephones in Fig. 1, isn't it?

A. No, it is the smoothing out of all of those. You couldn't hear those intermittent oscillations since they are super-audible.

Q. I don't think they are in the Figure 1. Doesn't he describe in Figure 1 an arrangement in which the intermittent oscillations are audible, and then go on and describe later the arrangement in Figure 2 in which the intermittent oscillations are super-audible?

A. Do you have some particular reference in the specifications?

Q. Well, yes, look at page 2, he says, line 100, or 99: "When receiving —" Professor Hazeltine tells me that there is no distinction between the two figures, that either figure could be used either way, but the point I had in mind was that the patentee describes two operations. Now, I direct your attention to it, at this point on page 2 he says:

> "When receiving undamped-wave telegraph signals, it is desirable to have the intermittent-oscillations occur at an audible frequency, hence eliminating the customary heterodyning step. However, when receiving continuous-wave telephone signals, a super-audible intermittent oscillation frequency should be employed."

Now, that means that he describes two ways of operating the system, one in which the intermittent oscillations are heard in the telephone and, in the other case they are not heard in the telephone.

A. Well, what we are discussing here is the reception

of the undamped wave, as he calls it, type of signal in which he says the intermittent oscillations take place at a super-audible frequency, and that is exactly what I had in mind.

Q. From your description you had in mind all the time the second form in which the oscillations are brought about in super-audible frequencies?

A. I had that in mind, but it applies equally to the other with the single exception that in the reception of damped wave telegraph signals an audible frequency is selected, that is the only difference.

Q. That is, an audible frequency of intermittent oscillations.

Mr. Adams: Undamped wave.

A. Did I say damped wave?

Q. Undamped wave?

A. I meant damped waves for the audible. That is what he says. I am sorry, he does say undamped. That is correct.

Q. Well, I think we all got a little mixed up, and the point is in the case of telegraph signals he has an arrangement in which these intermittent oscillations are at audible frequency, whereas in the case of using the system for telephony he would have the other arrangement in which the intermittent oscillations are of super-audible frequency, is that your understanding of it?

A. That is it exactly.

Q. Did you ever know of any practical use of a super-regenerative system in which the operation was controlled by a rectifier like this Slepian proposal?

A. I don't know of any one that was constructed.

Q. Now, when you look at the patent to Heising—

Mr. Darby: Tab 12.

Q. —where again there is the use of a diode, Mr. Darby asked you about that patent, he said, "And does

Heising employ a diode or two-electrode rectifier in his automatic amplification control for the same purpose and in the same manner as it is employed in the Wheeler re-issue", and you said, "In a general way; yes, sir," and he asked, "That is they are both for rectifying purposes?" The answer was "Yes." That is your testimony, that both Heising and Wheeler used the diode for rectifying purposes.

A. Yes, and also for developing a negative voltage to be applied to the grids of the controlled amplifier.

Q. But beyond that you agree, I think, with me, Mr. Kelley, that you testified that the purpose of Heising was quite different from the purpose of Wheeler, that is, Heising had in mind regulating the efficiency or producing an efficient amplifier, which would amplify the weak signals just as well as it amplified the strong signals, whereas Wheeler had in mind a system which would limit the upper value of the amplification so that no signal could be produced louder than a given value?

A. I believe I pointed that out, Mr. Davis.

Q. You pointed out, or mentioned in your testimony about Heising, that it dealt with zero carrier waves; what does that mean?

A. That means that the modulated carrier wave signal has the carrier frequency suppressed.

Q. In other words, the carrier wave which Wheeler uses to produce directly the potential that controls his system is absent, has been taken out of the Heising signal before he handled it at all, is that right?

A. Well, in Wheeler's circuit he includes as well with the carrier, its modulation. In Heising, that is zero carrier wave, the carrier only has been taken away, leaving the modulation; that is the side frequencies associated with the carrier wave.

Q. Well, Mr. Wheeler took the trouble to keep his

modulation from ever getting to the grid of his—to the control grid of the amplifier and passing only the direct current component corresponding to the carrier, didn't he?

A. No. I thought you were talking about, and the only thing I can see that is pertinent, is what does the diode in Heising get to rectify.

Q. All right. As I understood you to say, what Heising gets in his diode to rectify is the modulation?

A. That is right. But, that is the modulation, meaning by that at the carrier frequency level of frequency.

Q. Yes.

A. I don't mean modulation frequency as it has been spoken of before as audio-frequency.

Q. I understand that. But, the point I am making is that in this Heising system, the carrier has been removed?

A. That is right.

Q. Now, will you look at the second column of page 2 where it says:

> "The wave form of the curve MN"—line 3, which is shown in Figure 4—"The wave form of the curve MN suggests at once that it is periodic and that its fundamental frequency is twice that of the signaling wave s".

Now, the curve MN represents the potential, the rectified potential applied to the grid by the Heising system, doesn't it?

A. Yes, sir.

Q. And, it is a potential that is of a frequency, twice the frequency of the modulation?

A. Yes, sir.

Q. And, you will agree with me, I think, that there is nothing of that kind in Wheeler's system?

A. This is a different type in the sense that I pointed

it out, but it employs instrumentalities such as the diode and the use of the diode to rectify the current, signal current received for the purpose of controlling through the negative voltage developed in the circuit of the diode rectifier the effect of the amplification of the control amplifier tube.

Q. Yes, Mr. Kelley, you can go that far with a generalization, but don't you agree with me when you get down specifically not to the similarities, but the differences between the systems, don't you come to the fact that Heising used his system arrangement to produce a potential on the grid which was twice the frequency of the modulation? You agree with that?

A. Well, that is the fact, but that happens to be twice the frequency of the modulation because that is the control that he is effecting. It just happens to be twice.

Q. But, he says it is an important feature of his invention, doesn't he?

A. He says it is twice, and I don't see that there is anything more to say about it.

Q. I don't, either, except to answer my question which was whether there was anything of that kind in Wheeler?

A. I think I had already answered that. The answer is no, nothing like that.

Q. Now, will you look with me at the Schelleng patent. Now, Mr. Schelleng says at the beginning of his specification that his invention relates to amplifying systems, and more particularly to devices for limiting the output. And, a little lower down he points out that he wants to limit this within a desired safe value and that a feature of the invention is a voltage-limiting device so connected between the output and input circuits of the power amplifier that an excessive voltage in the output circuit reduces the power supplied to the amplifier. And, I want you to follow a little with the drawing and see if I have it right. In the first place, the box marked 1 produces a modulated carrier wave?

A. Yes, sir.

Q. And that is supplied through the transformer 2 to the amplifier 3, and in the box marked "power amplifiers" there are probably a series of amplifiers like 3. It goes through, then, to the amplifier 4, and then through the output circuit of the amplifier 4, the transformer 7, it is impressed on the antennae of the system as a transmitted radio message?

A. Yes, sir.

Q. Now, the purpose, as I understand it of this invention is to put into that system a safety device so that large surges of power will not go onto the antennae, is that right?

A. That is substantially correct. When the signal which is being fed to the antennae, or rather, which is coming to the amplifier, and then being amplified, and finally impressed upon the antennae, has large increases in amplitude which are beyond the ability of the amplifier to handle satisfactorily, he wants, by means of this amplification control circuit, to prevent the increases in amplitude from exceeding a safe value.

Q. In the normal operation of the system, when it is operating within the safety limit, it just operates as I described it already, and the safety device doesn't come into play, but undesirable large surges of energy, then the safety device comes into play to prevent that surge going to the transmitter, to the antennae, is that right?

A. Yes, sir. It could be applied also, and I think it is within the teaching of the patent, to a system where every so often, I mean that the normal condition would be that such increases in amplitude would occur rather frequently, but not frequently enough to cause the control to be working continuously.

Q. That is, if the abnormality came often enough so that it is almost normal, the thing would still work

whenever the abnormality came; that is what you mean?

A. No, I wouldn't use the word "abnormality" there for this reason, remember that Schelleng is here showing a transmitting, radio transmitter, and one of the serious problems in connection with a radio transmitter is to be able to handle all the power that will be transmitted to the antennae and also to be able to transmit the so-called dynamic range of a sufficiently wide character.

For instance, a symphony orchestra playing has been found to have loud and soft passages that are as much as three thousand times; that is, the loud passages may be three thousand times the intensity of the very soft passage; whereas, to be able to get that range in the transmitter would be a very serious problem so that you could select out, using the Schelleng arrangement the upper limit of that you consider to be satisfactory as a transmission and exclude what went beyond. So that, on all the occasions when the extremely large amplitudes were not desired to be transmitted, they would be generally suppressed, or at least not allowed to go to their full extent.

Q. Well, now, I want to find out with you how that upper limit is fixed in the Schelleng patent, and I am going to follow through and see if you agree with me. He takes off from the output circuit of the tube 4, through the conductors, 22 and 23, a certain amount of the energy that is, of the amplified modulated signal, and he brings that down through the wires there, through the coupling condenser, 12, to the diode, 9, that is right, so far, isn't it?

A. Yes, sir.

Q. And is there in there any filtering circuit as 13 and 12, constitute a filter?

A. Well, it would have a tuned frequency, yes, sir.

Q. And would keep out the direct current components, too, wouldn't it?

A. Yes, the condenser, 12, would serve that.

Q. Now, the alternating current energy thus impressed on the tube, 9, is rectified by that diode action, is that right?

A. Yes, sir.

Q. And that goes on through a filter, 15, which takes out the radio frequency, any radio frequency components in it?

A. Yes, sir.

Q. So that we have beyond 15, a direct current component from the diode, 9?

A. Yes, sir.

Q. And that flows through the resistance 18, or at least it might flow through that resistance, that is the path, down to the battery, 20, and is opposed—it flows in such a direction that the potential that current creates in the resistance, 18, is opposed to the potential of the battery, 20?

A. Yes, sir.

Q. That is the way the upper limit is fixed, isn't it, until the current flowing through 18 produces a potential which overcomes the potential of the battery, 20, this safety device remains out of action?

A. That is right.

Q. And as soon as that potential is high enough to overcome the battery, 20, it goes into action?

A. Yes, sir.

Q. All right. Now, let's assume that that has occurred, so that the potential at the upper end, so that there is at the upper end of the resistance, 18, a positive potential, and that potential is fed through the wires there to the plate, or anode, of the diode, 19, isn't it?

A. The potential is positive with respect to the other end of 18, and there is a connection from that positive end through battery, 21, and the secondary of trans-

former, 2,—I am sorry, around the other way, to the right, up through battery, 5, the coil, 6, to the plate.

Q. That takes that potential to the plate of the diode, 19?

A. Oh, I thought you said the plate of the amplifier tube. There is a connection that you can follow around to the upper end of resistance, 18, through battery, 21, secondary of transformer, 2, and then down back to the anode or plate of the diode, 19.

Q. And that puts a positive potential on the anode of the diode, 19, and causes it to become a current-carrying device, so that a current flows through that circuit; that is right, isn't it?

A. Under the conditions where the voltage across 18 is sufficient to overcome the battery, 20, that is right.

Q. Yes, and then as the safety device has now gone into operation, and it operates by permitting the current to be taken off through the circuit I have just described from the input circuit of the first amplifier, 3, a shunt circuit?

A. Yes, sir.

Q. And that is the grid circuit of the first amplifier, isn't it?

A. It is across the grid circuit, that is, in shunt to the grid circuit of the first amplifier.

Q. Being in shunt to the grid circuit of the first amplifier, any flow of current in it would cause distortion, wouldn't it?

A. It would depend how great the shunt happened to be; it would tend to cause distortion.

The Court: We will take a short recess.

(Recess.)

Q. (By Mr. Davis): Mr. Kelley, yesterday you were asked by Mr. Darby to refer to the Wheeler re-issue patent, page 2, line 46, in the first column, and to dis-

cuss what is there described, and you read from the patent the description of the rejector circuit, and pointed out how it was embodied in the resistance 34 and by-pass condenser 37 in the Wheeler drawing, Figure 1, and then you went on to say, in answer to further questions, that defendant's receivers do not have that rejector circuit. The purpose of the rejector circuit is to keep the alternating current variations out of the direct, so-called direct current connection that goes back to the grid, isn't it?

A. The rejector circuit serves that function in the circuit shown in the Wheeler patent on account of the special connection of the resistance 51 and condenser 2. Otherwise it would not be needed.

Q. Well, it is necessary in all of these systems that we are discussing, to keep the alternating current variations out of the control potential that goes back to the grid of the amplifier, isn't it?

A. Oh, yes.

Q. Otherwise, there would be a feed-back of that alternating current at that alternating current frequency in the amplifier tubes that would cause oscillation?

A. In the case in the circuit shown in the Wheeler patent, the radio frequency currents would not be prevented from getting into the input circuit of the audio-frequency amplifier. It is a different circuit arrangement.

Q. What I was asking you, Mr. Kelley—I heard you say that and you described it yesterday—but the point I am getting at is that in the—I will ask you this question directly. In the defendant's circuit, it is true that these radio frequency alternations are kept out of the—first, I will ask you of the connection that goes back to the grid of the amplifier?

A. Yes, sir; but by the condenser which was marked 2 on each of the Exhibits 2-B and 3-B.

Q. And it was your position yesterday that the portion of the resistance which is marked 34 by Professor Hazeltine did not perform any function in the way of rejecting that alternating current variation?

A. It was my position that the resistance 34, that is, the one that is labelled 34 on Plaintiff's Exhibits 2-B and 3-B does not correspond in function to the resistance 34 in Figure 1 of the Wheeler patent, and that necessarily so, because I find no designation 37 for the condenser 37 which appears in the Figure 1 of the Wheeler patent which forms a part of this rejector circuit. That is, you can't take resistance 34 and find its counterpart. You have to find the counterpart also of the condenser 37.

Q. And that condenser, as I think you said yesterday. At any rate I will ask you, that condenser has to be beyond the resistance 34, that is, in the direction of the junction point 52 in order to serve the function of the rejector circuit, is that right?

A. Well, the condenser 2 is simply a radio frequency by-pass for the entire resistance comprising 34 and 51 in series.

Q. I don't think you understood my question. Perhaps it was very blind. What I had in mind is what you have just told us, you don't find in the defendant's system the combination of a resistance 34, with an appropriate condenser, and I suggested that in order to be appropriate for this rejector purpose—I was trying to find out whether or not that condenser would have to be—where that condenser would have to be, and I will ask you this question: If you had a condenser in this circuit of the Detrola Model 175, or if there was a capacity coupling, which is the same thing, as I understand it, as a condenser, between the circuit in the region of the junction point 52, between the circuits in the region of the junction point 52, would such a capacity coupling serve the purpose of condenser 37?

A. In the first place, it is not there, and in the second place it would not, because I will now call your attention to the fact that the resistance which is labelled 34 in both Exhibits 2-B and 3-B is given on the prints from which these photostats were taken as having a value of 50,000 ohms, whereas what Wheeler calls the resistance 34 in his specification on page 2 in the paragraph beginning in the second column in line 31 he assigns a value of one megohm to resistance 34. In other words, one megohm is one million ohms. And what is labelled as 34, besides being in the wrong part of the circuit, I mean it doesn't correspond, besides that, the resistance which is labelled 34 on Exhibits 2-B and 3-B is thus only one-twentieth of the value of the resistance 34 given in the specification where I pointed it out, and in addition to that the necessary cooperating condenser 37, which is an essential part of his rejector circuit finds no counter part and is not indicated, even by the numeral 37 on Plaintiff's Exhibits 2-B and 3-B.

Q. Well, I understand that that capacity coupling represented by 37 in the Wheeler patent would have to be between the connections beyond the resistance 34 there and the ground. I said in my last question between the circuits and I am now making that more specific, and you say in the opening of your last answer, you say that there is no such capacity coupling present.

Now, I am asking you this: If there were such a capacity coupling present, and although not indicated on the drawing would it then cooperate with the resistance 34 to have the rejector effect?

A. Would still be a different circuit. You mean if you add a condenser between, say, the junction point 52 and the cathode. I assume that is approximately what you mean.

Q. Well, I didn't mean if you added one. I under-

stand there are in these sets, if you don't take care to prevent, and even sometimes if you do, there are inherent capacity couplings between two points which are at different electrical potentials and I am saying if there is such an inherent capacity coupling at that point in the defendant's sets, would it serve as a rejector circuit?

A. No, sir.

Mr. Davis: All right. I think, perhaps, your Honor—I don't want to waste any more time on this. I will leave it to rebuttal. At any rate, the rejector circuit is not included as part of the Wheeler invention in any of the claims, so it isn't very important. It is an environmental element of the system that is not represented to be any part of the Wheeler invention.

Q. Now, you were asked a little later by Mr. Darby yesterday, about the means for manually adjusting the desired level of the signal in the Wheeler patent, and you pointed out that Wheeler in his patent makes use of an adjustment of the resistance in the circuit which heats the filament of his tube, is that right?

A. Yes, sir.

Q. And the tubes that are used today do not have the filaments which are heated by a current that flows through them as they did at that time, but are heated indirectly, is that right?

A. For the most part that is right. There still are tubes which are directly heated and are used as such.

Q. But no such tube is used in defendant's set. They use the indirectly heated tubes?

A. I think that is right.

Q. And where is the manual adjustment in defendant's sets by which they control the level of the signal? That corresponds to the little knob, as I understand it, that the user of the set turns to make his reception louder or softer?

A. Yes. Well, referring first to Plaintiff's Exhibit 2-B, that adjustment is, in effect, an adjustment making 51, resistance 51, into an adjustable potentiometer. If you will see the little arrowhead about in the middle of what is labelled 51 on Exhibit 2-B, the light line, that arrowhead indicates an adjustable or sliding contact which will include more or less of the lower part of resistance 51, and thus increase or decrease the potential which is taken off. And, in that way, the control of the —the manual control of the volume is effected.

Q. That is by manually sliding this arrow up and down the resistance you vary the amount of potential that is fed through that battery connected to the arrowhead to the grid of the first stage of the audio-frequency amplification, is that right?

A. No, what you are feeding is not what comes from that battery. I don't know what battery you meant when you said that.

Mr. Davis: Did I say battery?

The Witness: I think you did.

Mr. Davis: Read the question.

(Last question read.)

Mr. Davis: "Through that condenser", I should have said.

A. Well, you merely vary the potential that is picked off by this sliding connection. The application of that potential is through the condenser C-21, and thence upward to the control grid of the triode section of the 75 tube.

Q. And the potential so picked off corresponds to the modulations of the signal?

A. That is the audio-frequency variation.

Q. Well, would you say that that arrangement is rationally described by the words "manually adjustable

means for determining the modulation frequency amplification"?

A. Yes, sir.

Q. I was reading that from claim 13. You pointed out, and we covered it earlier, that there was no neutralization in this set of defendant's?

A. Or either of them.

Q. Yes. And that was because the screen grid tubes did away with the necessity of neutralization really, wasn't it?

A. That is one reason.

Mr. Davis: I call the Court's attention at this point to the fact that neutralization is no part of Wheeler's invention, and is not brought into any of the claims.

Q. Now, you were asked yesterday by Mr. Darby this question: Referring to the circuits, Plaintiff's Exhibit 2-B and 3-B of defendant's receivers, and with reference to the tube 75, what is the output electrode of that tube? You said, "Well, in both instances, it is the anode or plate of the triode section." I want you to have that in mind as I question you a little further about it. As I understand it, the electron stream,—we have covered this before, but I want to check it again—the electron stream through the tube which corresponds to the signal impressed on the rectifier tube in the defendant's set 2-B flows from the cathode which is marked 38 on 2-B to the anode marked 35-12, and so through the coil 31, the resistance 34 and 51, and back to the cathode 38. We have already covered that, but that is correct, isn't it?

A. Yes, sir.

Q. That is, that electron stream is taken out of the tube at that anode, 35-12, and is then used to produce the control potential?

A. Just a minute, Mr. Davis. What do you mean by

that electron stream? Are you now speaking of fluctuating or alternating potentials or current?

Q. No, we have already brought out that there is a stream of electrons across the tube which varies according to the strength of the signal impressed on the tube, and which creates a negative potential on the anode 35-12; am I right so far?

A. That is right.

Q. And that potential is led out of the tube and through this circuit, including the resistance 51, and the current, as I understand it, flows out there and through the resistance 51; is that right?

A. What current?

Q. Well, what ever current flows in the circuit?

A. Well, because there is direct current there and the direct current flows into the anode.

Q. Well, I know, but now you are mixing us up with the fact that the ancient gentleman in the electrical business called, or mis-named the direction of flow of the current. The actual electron stream flows the other way, doesn't it?

A. The hand of the dead is controlling the hand of the living in that particular convention, because that is precisely the way it is used today. I mean that convention is today what would determine direction of flow.

Q. I understand, but what I am asking you is how the electron stream flows?

A. The electron stream must proceed from the cathode to the anode.

Q. All right. Now, something is taken out of that tube from the anode, 35-12; suppose you tell me what it is?

A. Well, there is nothing really taken out of the tube. There is something actually put into the tube, and the tube responds to that stimulant in a certain way, and

whatever other things that are in the circuit are affected by being connected in a series circuit. That is, you take the coil, 31, and the diode, the condenser, 2, with 34 and 51 in the series connected in shunt to 2, and you have a series circuit. Now, you have, with a given signal applying to that circuit, a certain current flowing in that circuit, and that is the response to it. You have a simple series circuit—

Q. (Interrupting): What you have just said, your whole last answer exactly describes what happens in the system of the Wheeler patent with respect to the connection of the anode of the diode to the a.v.c. circuit, doesn't it?

A. No, sir. In the Wheeler circuit the coil, the input coil, the 31 coil, is connected between the anode and the cathode of the diode, and the resistance, 51, is connected directly across, or in shunt to that, and there is also included in the Wheeler circuit between the coil, 31 and the anode of the diode, a series condenser which is labelled "2".

Q. That is, to simplify that rather elaborate statement, by saying that the defendant has taken the condenser, 2, of Wheeler, and moved it out of the lead that runs to the anode from the top of the coil, 31, and put it in the lead that runs to the cathode from the bottom of that coil; is that a fair statement?

A. No, it isn't. It is a different circuit.

Q. Well, the circuit is made different by just that exchange of the position of the condenser, isn't it?

A. Well, you are implying that you start with the circuit in the patent, and then from that you get this. That is what I do not agree with. What I do say is that the product which is produced as a result of this circuit in the resistances 34 and 51, in series as shown on Exhibit 2-B, is functionally the same as—in other

words, the product that is developed in that series of resistance, 34 and 51, is a DC which is the result of detection in the way that 51 in the patent in a different circuit arrangement also develops a direct current potential across it. There are two different ways of doing it.

Q. Well, as I understand the construction and arrangement of this 75 tube in the defendant's system, there is a connection, as shown on this diagram, to the anode of the diode section, which is at one end of the tube; is that right?

A. There is a connection.

Q. And that connection is the automatic volume control circuit?

A. Would you mind pointing out that connection, please, the one that you have in mind?

Q. As I understand, the connection is such that the diode portion of the 75 tube is connected in the automatic volume control circuit in the manner shown on this diagram, 2-B. That is, the anode is connected to the top of the coil, 31, and then through the path which we have already traced, the circuit is completed through the resistance 34-51, ground, back to the cathode section of the 75 tube that stands opposite the anode, 35-12, is that right?

A. So far that is right.

Q. Now, then, from that circuit at the point where the little arrow is on the resistance, 51, you have explained that a potential corresponding to the audio-frequency modulations is taken off through that condenser and is brought back into the tube 75 to the grid which is in the triode section of the tube; this is right, isn't it?

A. That is right, and that is at the audio-frequency.

Q. Now, that grid stands in a second stream of electrons, or electron path, from the upper section of the

cathode of the tube 75 to the anode of that section; is that right?

A. Yes, sir.

Q. And between those two electron streams, that is, the diode stream and the triode stream, there is in this construction of the tube a metallic shield called on this Exhibit "EE" called the disc shield, is that right?

A. Yes, sir.

Q. And in addition to that the anode section of the tube is surrounded by another shield called the tubular shield?

A. Yes, sir.

Q. And all that is to make the diode section and the triode section of the 75 tube act as two different electron streams, the equivalent of two different tubes in a single glass casing, isn't it?

A. Yes, sir.

Q. Well, if you had to identify the output electrode of the diode section of that tube, what electrode would you name?

A. I wouldn't name either electrode, because neither one functions as either an input or an output electrode, but what I would name as the output of the detector circuit is this arrowhead connection to the resistance 51. That is where the signals come out and are applied to the control grid of the triode section. As a matter of fact, the coil 31 is an input coil, so that we have between the anode and the place where the signal is taken off an input circuit, so that it becomes impossible to designate one or the other either input or output electrode.

Q. At what electrode of the diode is the output potential that corresponds to the direct current component and also the output potential that corresponds to the modulation frequency?

A. The potential for the direct current is developed in the resistance 51 and 34. The output for that coming out of this detector circuit is at the connection 52.

Q. I am talking about coming out of the diode, not coming out of the circuit. How does the energy get out of the diode?

A. The energy doesn't get out of the diode in the sense that something goes in and something goes out. It is connected in series. Mr. Davis, I think we are just discussing words here, because the term "output" doesn't apply in this circuit, and the use of that word, as I understand it, and have understood it ever since I have been in this art, would not apply, either input or output as a designation to the anode or cathode of the diode in this circuit. It is a functional designation and its use is well known and understood.

Q. Well, now, will you direct your attention to another matter, that is, the connection of the meter or visual indicator in the defendant's system. On your direct examination you referred to page 3, line 16, column 2, of the Wheeler patent, where the specification says: "The milliameter 10 is connected in the anode circuit of the amplifier vacuum tube 9", and you pointed out that on the drawing of the Wheeler patent, Figure 1, that it was so connected on that drawing, and then Mr. Darby asked you to refer to the drawings of the defendant's Model 175, Plaintiff's Exhibit 2-B, and to state whether or not and I am using his language, "The visual indicator employed in that receiver is located in the same circuit as specified by the Wheeler patent", and you said, "No, it is not." Now, you meant, I take it, that it was not located in the anode circuit of the vacuum tube 9?

A. That is right, or coupled to it.

Q. Well, do you say that in the defendant's set, the

visual meter is or is not coupled to the output circuit of the amplifier?

A. It is not coupled to the output circuit of the amplifier.

Q. Well, in what sense do you say that? I mean to say, it is actually responsive to the energy in that circuit, isn't it?

A. Well, that is not the way to determine whether one thing is coupled to another.

Q. Now, wait a minute. All you are saying is that that is not your definition of coupling, and all I am asking is is it so related to the output circuit that its indication corresponds to the energy in the output circuit of the amplifier?

A. No, sir.

Q. You think not?

A. I do.

Mr. Davis: I think that is all.

The Court: Do you have some extra copies of these Exhibits 2-B and 3-B, Mr. Davis?

Mr. Davis: Yes, sir.

The Court: I don't want them. I was wondering, or I thought it might help me some if you took a red pencil and traced that circuit on one of these you were just discussing with the witness.

Mr. Davis: I will.

Mr. Darby: That is, the visual indicator circuit?

The Court: What he called the output circuit to the visual indicator.

Mr. Davis: Why shouldn't we do that right now with the witness and get it on the record?

Mr. Darby: Surely. I was just going to ask the witness to do that very thing. That was my first question.

The Court: I have a red pencil.

A. Do you have a clean copy? I have a red pencil.

Mr. Davis: Here is a clean copy (handing paper to the witness).

Mr. Darby: It is only on Exhibit 2-B. There is no visual indicator on Exhibit 3-B.

The Court: Yes. I understand.

Q. (By Mr. Davis): Now, will you mark with a red pencil the circuit of the tuning meter—wait—of the tuning indicator in the defendant's model?

A. With a red circle? Do you want to put a circle around it?

Q. Do you want to trace the circuit?

A. I have already done so in red on this clean sheet, photostatic copy of the circuit.

Mr. Davis: Shall we put that in evidence?

Mr. Darby: Yes, put it right in. I have no objection. Put it in as Plaintiff's Exhibit 2-B-1.

(The photostatic sheet traced in red by the witness was marked Plaintiff's Exhibit 2-B-1.)

The Court: May I see that?

Mr. Davis: Yes. That is all.

Re-Direct Examination

By Mr. Darby:

Q. Now, will you please describe that circuit, having in mind the tracing in red that you have made on Plaintiff's Exhibit 2-B-1?

A. First, I will repeat what that circuit in red connects.

Q. All right.

A. The circuit in red begins at the point 52, proceeds to the left to 53 and to the junction point first encountered and down on that light line to the control grid of the

tube which is marked 6-G-5. This tube is the Magic Eye tube. It is responsive only to variations in potential. The variations in potential occurring at the point 52 under the influence of the detector action comprises the whole circuit of the diode, that is, the coil 31, the diode, the resistance 34 in series with 51, in conjunction with the condenser 2, back to the cathode. The direct current potential developed in the resistance 51 up to the point 52 is the potential which is applied to the control grid of the Magic Eye tube 6-G-5. That is all there is to it.

Q. Now, while you have the diagram of the defendant's receiver before you, will you likewise put in front of you the figure one of the Wheeler patent, and I would like to crystallize very briefly this subject of rejector circuit. Now, I understood you to say in response to a question of Mr. Davis that in all automatic amplification control systems, you do not want the alternating current component to be present in the automatic amplification control circuit; is that right?

A. That is right.

Q. And the rejector circuit is employed by Wheeler as part of his particular type of automatic amplification control, is that right?

A. Yes, sir.

Q. The defendant, if I understood you correctly, likewise avoids having alternating current components in its automatic amplification control circuit, is that right?

A. Yes, sir.

Q. Now, why is it that defendant obtains that result without the use of the rejector circuit including the resistance 34 and the condenser 37 in the Wheeler arrangement?

A. Well, for this reason; refer, first, to the Wheeler circuit shown in Figure 1 of the drawing.

Q. I didn't want—

A. (Interrupting): I think it would be desirable—

Q. (Interposing): All right.

A. (Continuing): To point out what the circuit is.

Q. All right.

A. And show wherein it is different. The condenser 2 there is shown to be connected between the input coil 31 and the anode of the diode. That is between that connection. There is no corresponding connection in the defendant's circuit. That is when you consider its relationship to the resistance 51, because we now find that the resistance 51, instead of being connected in shunt or across the condenser 2 is connected in shunt or across the diode itself, and the condenser 2 and the resistance 51 in the Wheeler circuit cooperate in the detector circuit to produce the voltage which is then going to be used, both for automatic amplification control and audio-frequency amplification.

Now, referring to Exhibit 2-B, the condenser which is there labelled 2, and the resistance 34 in series with the resistance 51, are connected in parallel or in shunt to each other, and included in series in the detector circuit that is in series with the diode. So that automatically the desired frequencies that one wishes to get rid of are by-passed by the condenser 2 in the defendant's circuit, Exhibit 2-B; whereas, the condenser 2 in Figure 1 of the Wheeler patent does not prevent in any way the high frequencies that one desires to get rid of from getting into the circuit which is utilized for automatic amplification control and audio-frequency amplification.

As I expressed it in my testimony the other day the position of the condenser 2 exposes the circuits that are connected to the rectifier to these alternating currents and it then becomes necessary to add a rejector circuit of some kind, and a rejector circuit which is added in the Wheeler circuit is comprised of the resistance 34 and the condenser 37.

Q. Is the rejector circuit consisting of the resistance 34 and the condenser 37 essential in Wheeler's automatic amplification control arrangement?

A. Yes, sir.

Q. Why isn't it essential in the defendant's apparatus?

A. Because the circuit is different.

Q. If Wheeler's invention consists of the use of the particular amplification control circuit shown in his drawings, is his invention utilized in defendant's receivers?

A. No, sir.

Q. In the arrangement shown in the Wheeler patent, does any of the direct current which goes through resistance 51, go through the resistance 34?

A. No.

Q. In the Detrola arrangement, the defendant's arrangement, does all of the direct current that goes through 51 go through 34?

A. Yes, sir.

Q. Is that the reason why, in producing defendant's Exhibits U and V, the simplified wiring diagrams of Defendant's arrangement that you have labelled the two resistances 51 is used?

A. That is correct.

Q. Does the fact that in the defendant's arrangement all of the direct current goes through both resistances 51 and 34 necessarily make resistance 34 a part of resistance 51 insofar as automatic amplification control is concerned?

A. Yes, sir.

Q. Now, just one or two minor matters and we are through, your Honor. In your cross examination you referred to the use by you in your work with the Western Electric Company of triode tubes operating in connection with carrier frequency work on or substantially on linear characteristics, but in that part of your testimony you

didn't give the date. Could you give me the date approximately?

A. Beginning in 1920.

Q. You also mentioned in connection with carrier work, the term radio link. What do you mean by that "radio link" in carrier wired wireless?

A. I could best illustrate that by imagining somebody from Detroit putting in a transatlantic telephone call to some place outside of the point of reception on the other side.

Q. You mean somewhere in Europe.

A. Somewhere in Europe, that is connected by land line to the receiving radio station. The land line between Detroit and the greater transmitters would be the land line link. The gap through space, that is where the radio part is carried on would be the radio link, and similarly the land line connection at the other end would be the land line link.

Q. And is it a fact, or is it not a fact, that every problem encountered in radio communication is encountered in the radio link of carrier frequency communication?

A. Yes.

Q. In the land links of carrier frequency work is there encountered the problems incident to variation of volume which makes automatic amplification control insofar as applicable to volume desirable?

A. Yes, sir.

Q. Is that true regardless of the factors, of the cause of any variation in volume?

A. Yes, the variation in volume itself is the reason for using the automatic amplification control.

Q. Having in mind that we have referred in this case to R. C. A. or Radio Corporation patents as including all of the patents of the Radio Corporation, West-

inghouse, Western Electric, A. T. & T. and perhaps others?

Mr. Adams: General Electric.

Q. (By Mr. Darby): General Electric; do you know of your own knowledge how many patents are included in that group of R. C. A. patents?

A. I don't know how many but I understand it is in the thousands.

Q. Can you state approximately how many?

A. About 5 or 6 thousand is my understanding.

Mr. Darby: That is all, your Honor. Have you any further questions?

Re-Cross Examination

By Mr. Davis:

Q. I suppose, Mr. Kelley, that one problem that is not encountered by the user of a transatlantic telephone line, even it has a radio link, is the problem of adjusting his own receiver to the volume and to the station that he desires, corresponding to the problem that confronts the operator of a broadcast receiving set.

A. I was thinking of the vagaries of the transmission through the ether which are present in both cases, and which necessitates or makes desirable, I should say, some form of automatic amplification control, whether or not you have this additional operation of tuning that you mentioned. That is adjusting for one station to the other.

Q. But the user of the telephone is not confronted with any problem of adjusting the circuit, that is all done for him somewhere else in the telephone system, isn't it?

A. Well, the telephone company has to do it.

Q. Well, now, do you know when the telephone com-

pany first used an automatic volume control by grid bias on the amplifiers?

A. No, sir.

Q. You did not know of it while you worked for them, did you?

A. I do not remember that, Mr. Davis.

Q. You mean you do not remember whether you knew of it or not?

A. That is right.

Mr. Davis: That is all.

Mr. Darby: That is all, thank you, Mr. Kelley, and the defendant rests.

Mr. Davis: Professor Hazeltine.

PLAINTIFF'S TESTIMONY IN REBUTTAL

LOUIS ALAN HAZELTINE, thereupon resumed the stand, having been previously duly sworn, called in rebuttal by plaintiff, testified as follows:

Direct Examination

By Mr. Davis:

Q. Professor Hazeltine, will you turn to the Evans patent 1736852, and tell us as briefly as you can what sort of a system is shown in that patent?

A. This is rather an elaborate system for telephone communication over high voltage power lines.

Q. That is, as I understand it, the proposal was to put the telephone conversations in electrical form right on to the power lines that had already been erected, so as to use them for telephoning.

A. That is correct.

Q. As well as power?

A. That is correct.

Q. Will you proceed?

A. The part of this system that is of interest here is the arrangement for automatic volume control which is at the bottom of the middle in the figure of the Evans patent.

The Court: Wait a minute, is that Figure 1?

Mr. Adams: Figure 1.

The Court: All right.

A. Yes, Figure 1.

The Court: All right.

A. The signal may be traced from the input, at the lower right-horizontally through two vacuum tube amplifiers that are under the number 15.

Q. Well, Professor, let me interrupt you. I think perhaps in tracing this circuit we had better refer to the other Evans patent, because that is the one we used before.

As I understand it, the second Evans patent, number 1869823, which is a division of the patent you are now looking at, contains the same automatic volume control arrangement as that one you were just referred to in the original patent, is that right?

A. That is correct.

Q. And then will you proceed with your description with reference to the single figure of the Evans patent, 1869823?

A. Here the input which I referred to in my last answer, is between the points marked 1 and 2.

Q. Let me interrupt you there. It is over that input that the so-called wired wireless signal that has been put on the power line comes into this receiver, is that right?

A. That is correct.

Q. Now proceed.

A. That signal is then amplified by the two vacuum tube amplifiers marked 5 and 4. After amplification it is then impressed on the grid of the detector tube marked 8. This is a triode detector or rectifier. From its plate, the electrode at the left, a signal current flows through the primary or transformer 10, and for simplicity we may trace it through the connections at 12 and 13, supposing the contact to be closed at the bottom, then up to a junction point below the numeral 23 and thence through the batteries, 16, which is the so-called B battery for the detector tube. At that point the signal current and the direct current divide. The circuit for direct current goes through the resistance marked 19, and then to the point at which the ground is shown, and vertically upward to the battery 14 which heats the filament, and thence to the filament or cathode itself. The signal current—

Q. (Interrupting): Let me interrupt you again, Professor. When you speak of signal current, it has been variously referred to here as the modulation frequency current and audio-frequency current, is that right?

A. That is right. That signal current has two functions to perform. It has to pass on the modulation of the audio-frequency part of the signal and that is done through the transformer 10, the secondary circuit of which is at the upper left-hand corner, and from which two leads are brought off that go ultimately to the telephone receiver.

The other function which that signal current performs is to provide a potential for automatic volume control, and that potential is built up in the resistance 19. In that resistance 19 there will unavoidably be present also some modulation or audio components of potential. They are filtered out by the combination of condensers 21 and 22, together with the resistance 20.

After the modulation components have thus been filtered out, the direct-current potential remains, and that is conducted to the grid circuits of tubes 4 and 5 by the wires that pass first through the battery 18 and thence split, one circuit going upward just to the right of 18 and to the secondary coil of the transformer 7, and thence to the grid of the amplifier tube 4, to give its negative bias. The other circuit continues from near the numeral 18 to the right and similarly provides the negative bias for the grid of tube 5.

In the operation of the system the stronger the signal the greater will be the signal current in the plate circuit of the detector, thence the greater will be the direct-current potential built up in resistance 19 and thence the greater will be the negative potential that is impressed on the grids of tubes 4 and 5. This in turn lowers their amplification and gives the automatic volume control that is the object of this divisional patent.

Q. Professor, you heard Mr. Wheeler testify about his laboratory notebook and how he fixed up a set at his home in Washington during the Christmas holidays of 1925?

A. Yes.

Q. And that set did not work satisfactorily and then he changed it, do you remember that testimony?

A. Yes.

Q. And he testified that the circuit connections of the set that he set up in Washington and didn't get satisfactory results with, correspond to the circuit diagram on page 86 of his notebook, and I ask you if you have compared that circuit with the circuit of this Evans patent, and whether they are substantially the same?

A. Yes, I have made that comparison, and they are substantially the same.

Q. Now, you heard him testify that he then substituted

in his set the arrangement that is shown in Figure 1 of his patent here in suit, the automatic volume control arrangement?

A. Yes.

Q. In which a diode is used in series with a high resistance?

A. Yes.

Q. Now, will you say whether or not it is true with this diode arrangement of Figure 1 of the Wheeler patent that the automatic volume control potential is produced directly from the signal itself?

A. Yes, that is true.

Q. Will you say whether or not in the arrangement of the Evans patent the control potential is produced directly by the signal itself?

A. No, in the Evans patent the control potential is produced by the "B" battery 16, in the plate circuit of detector tube 8, and that energy is merely controlled by the signal.

Q. I wish you would briefly describe to us just how it is controlled, and what the relation of the "C" battery 17 is to that control?

A. In the proper operation of this detector, it is desirable to start off with a relatively small plate current, because the curvature of the common characteristic curve of the tube is the greatest at some small plate current. That point is reached by putting in the battery 17, known as a "C" battery or as a biasing battery. The potential supplied by that battery then is in critical balance with the potential supplied to the plate by its battery 16, so that if a designer should wish to vary the potential of the plate battery, he would at the same time have to vary the potential of the grid or "C" battery correspondingly.

Q. Before you leave that, tell us what effect upon

the operation, if any, there would be in case these batteries, or any potential source substituted for them, were not constant in value?

A. That would seriously interfere with the operation of the tube. If the plate battery were to fall off in potential, the C battery might sufficiently predominate to completely cut off the plate current, bringing the point on the characteristic curve below the so-called cut-off point. In that case, of course, the detector tube would entirely cease to function.

On the other hand, if the plate battery 16 had relatively too high a voltage as compared with the proper voltage to balance the grid bias battery 17, then the operating point on the characteristic curve would not be that giving best signal detection and best operation for the automatic volume control.

The Court: All right, we will adjourn at this time. Come back at two o'clock.

(Thereupon, a recess was taken until 2:00 o'clock P. M.)

Detroit, Michigan,
Wednesday, November 1, 1939,
2:00 o'clock P. M.

Court met pursuant to recess.

The Court: You may proceed.
Mr. Davis: All right, Professor.

LOUIS ALAN HAZELTINE, was thereupon recalled as a witness, being previously duly sworn, testified as follows:

Direct Examination (Continued)

By Mr. Davis:

Q. We were discussing this morning the Evans circuit arrangement of the drawing of his patent, and you had referred to the necessary critical adjustment or balancing of the plate battery 16 and the grid battery 17, and I was about to ask you about the characteristics of the tubes themselves and how that effects this balance, and just what is referred to by the expression, "the characteristics of the tube"?

A. The particular characteristic that enters into this discussion most directly is the so-called amplification factor. The amplification factor is the ratio of the change in plate potential to the change in grid potential that it would just compensate for. That is, if the plate potential had to be changed eight times as much as the grid potential and, of course, in the opposite direction, in order to leave the plate current the same, then the amplification factor would be called eight. To bring the tube to the cut-off point would require that the C voltage then be equal to one-eighth of the B voltage, assuming that that amplification factor was strictly constant over a wide range.

Irregularities in the manufacture of many tubes, especially some years ago, 1926, say, meant that there would be a variation in the amplification factor from one tube to another, even of the same type; so that if we had a system set up to balance the plate voltage and the grid bias voltage for one tube, then the substitution of another tube of the same type that had a different amplification factor, might appreciably upset the balance.

Q. Let me interrupt you there. In a broadcast receiv-

ing set, such as the Wheeler system or the defendant's set, any such upset as that would require a readjustment of the battery voltages by the user of the set in order to restore the correct operation of the set?

A. Yes, that is correct.

Q. And it is a fact, is it not, that no adjustment by the user of the battery voltages is contemplated in these broadcast radio receiving sets?

A. That is certainly true today and has generally been true.

Q. They have no means of readily adjusting these potentials even if the user knew how to go about it, is that right?

A. No; that is true.

Q. Will you proceed now with a discussion of the effect of the characteristics of the tube on this system?

A. Another characteristic of the tube is the plate resistance, sometimes called the plate impedance. That resistance will affect the operation of the tube particularly in the operation of the automatic volume control system, because the control potential that is obtained will depend upon the relation of the tube resistance to the external resistance in which the control potential is developed, that being the resistance 19 in the Evans patent. That is a less critical matter than the amplification factor to which I referred before, but also would have a tendency to upset the proper performance of the automatic volume control if one tube was substituted for another having a different plate resistance.

Q. Now, to get back to this variation in amplification factor on the several tubes, tell us what that depends on; that is, does it depend on the physical structure of the tubes themselves, or what?

A. Primarily on the physical structure. That is, it depends on the dimensions of the plate and the grid,

particularly on the spacing the grid wires and their spacing from the surface of the cathode, which here is the filament.

Q. Now, I will ask you to listen while I read a sentence or two from the Wheeler patent. At page 4, in the first column, beginning line 62, he is reciting certain advantages attending the use of the two-electrode rectifier in the circuit typified by Figures 1 and 3 of his patent. He says:

> "It is impossible to overload this type of rectifier, and the rectified output voltage is directly proportional to the applied alternating signal voltage when this voltage is large, say over two volts. The control system in the circuits of the figures referred to requires a large operating voltage, say 10 volts, so that the latter condition of large signal voltage is realized."

Now, do you agree with that statement, in the first place?

A. Yes, entirely.

Q. Can you tell us briefly why it is that the diode rectifier is impossible to overload and has this direct proportional relationship of the applied signal voltage to the rectified voltage?

A. The diode rectifier gets its energy directly from the signal and not from local batteries. There is no practical limitation to the strength of the signal that can be impressed on the diode rectifier, and the stronger the signal the better it operates that rectifier. That is, the more nearly linear its behavior is. The linear action which makes the rectified output voltage directly proportional to the signal voltage, or applied alternating voltage, occurs when the resistance external to the diode is large compared with the resistance of the diode itself,

and that is quite an easy condition to attain because the diode itself has a low resistance as tubes go; that is, its resistance is usually much lower than the plate resistance of a triode.

Now, in a triode we do not have those conditions. In a triode we have to have the critical balance between the plate voltage and the C voltage as applied by batteries, for example.

Q. Let me interrupt you there, Professor, to get in synchronism with what Mr. Wheeler says in his patent, and I will read the next sentence:

> "No such simple relationship is possible in a three-electrode detector, whose rectified output never exceeds a limiting upper value, and is never proportional to the applied voltage, except over a very small range of voltages."

Do you agree with that statement?

A. Yes.

Q. Now, will you explain it, making reference to the three-electrode detector, or rectifier, that is shown in the drawing of the Evans patent, to explain it?

A. As I explained previously, there is this balance between the C voltage of the battery 17, and the B voltage of the battery 16, which is quite essential, as I discussed this morning. The maximum permissible signal potential that may be impressed in the grid circuit is equal to the negative bias given by battery, 17. The reason for that is that the grid potential should not be allowed to become positive, because if it became positive, a current would flow in the grid circuit and that would produce distortion. That is the reason that the patent says, in your last quotation, that the "rectified output never exceeds a limiting upper value." The limiting upper value corresponding to the maximum signal which may be im-

pressed on the grid, which is equal to the C battery voltage. In that range of operation, with the values of B voltage and of resistances in the plate circuits that were customary at the time when the Evans original patent was filed, that is, in 1923, and for some years thereafter, the range of operation would not have given linear action, because the plate voltage and the resistance in the plate circuit such as 19, wouldn't have caused the external resistance, 19, to be appreciably larger or perhaps not even as large as the plate resistance of the triode, 8, itself, and for that reason the rectified output voltage would not be proportional to the applied voltage.

Q. As I understand it, for the small signal level that was customarily applied to the detector circuit in these receiving sets at the time, say, 1926, both the diode detector and the triode detector for those small signals would act in the patent on what is called the square law part of the curve, is that right?

A. Yes, signals less than about a volt.

Q. And it is when you go into the use of higher levels of signal voltage in the sets, that you get into this region where the linear response becomes important, is that right?

A. Yes, that is right.

Q. And you have just told us that it is in that, in the triode, there is this limiting condition or ceiling, so to speak, that cannot be exceeded without distortion?

A. That is correct.

Q. Now, I understand that it is at least theoretically possible to lift that ceiling in a triode circuit. How would you go about that?

A. If it is necessary to do that, it will be necessary to make three changes from the practice as it then existed. We would have then first to increase the value of resistance 19, by a fairly large factor, then we would

have to increase the plate voltage of battery 16, and then we would have to correspondingly increase the grid bias voltage in battery 17. Those changes, if carried far enough, would give substantially linear rectification, but of course at the expense of even more critical conditions than originally existed.

Q. Were you quite familiar with the practice in the radio art in 1926?

A. Generally speaking, yes. I was active in radio at that time and for some years previously.

Q. And you were familiar with the practice with respect to the voltage of signal used, and so forth, at that time?

A. Yes, in general.

Q. Well, at that time was the use of this high level of signal voltage that is used in the Wheeler system and is used in defendant's system. customary?

A. It was not customary to use that high voltage, and in fact, one was not accustomed to think in those terms. I was always accustomed to think of the voltage as being small enough so that the detection followed the square law, and that was the general understanding among engineers at that time.

Q. Now, you maybe have already explained, but at any rate will you explain again the significance of the relationship of the external resistance to the internal resistance of the tube, and how that relationship is important in the operation of an a.v.c. system?

A. It is important in order that linear rectification be obtained, and it is also important in order that the substitution of one tube for another shall not have an appreciable effect on the operation of the system. Both of those results are obtained if the external resistance is high compared with the tube resistance. The reason that linear rectification is desirable is that without it

there is a varying control, that is, the control potential will depend not merely on the carrier component of the signal, but also on the degree in which the carrier is modulated. If the rectification is linear, then the control does not depend on the degree of modulation, and that is the only way in which distortion can be wholly avoided.

Q. Now, referring again to this Evans patent, as I understand your testimony so far, it has been that a triode detector used in the way shown here, might respond on the square law with one proportioning of the batteries 16 and 17 and the resistance 19; with another proportioning of its resistances it might respond linearly, provided you impressed upon it this high level signal voltage; is that right?

A. That is correct, with the understanding that I find no suggestion in the Evans patent of the second alternative. As I read that patent I understand that you would operate the thing with the ordinary low signal level and with the moderate values of battery voltage and resistance that were current at that time, and in that case you would get the square law action, or a close approximation to it.

Q. You have heard the testimony here about Mr. Friis making up a radio-receiver with automatic volume control for the Western Electric Company?

A. Yes.

Q. And you have heard the testimony, or read that Mr. Friis said that in that system the resistance 19 had a value of about 20,000 ohms and that the tube had a resistance of about 30,000 ohms. Now, with such values as that, would the response be the linear response or the square law response?

A. It would give the square law response.

Q. Assuming such a proportioning in the values of the

system of Evans, that is, so that the response was the square law response and the small signals, and then consider what would be the distortion effect, if any, upon the audio-frequency or the modulation frequency, if as in Evans the signal carrier with the modulation on it were impressed directly on the detector?

A. The distortion effect that occurs in this arrangement is one in which the control potential will be less with low degrees of modulation. The final effect is a partial elimination of the contrast. That is, a relatively loud sound would not appear so loud when reproduced, because its additional loudness would increase the negative potential of the automatic volume control and so would weaken it. That kind of distortion would be objectionable in the reception of a good musical program. It would not be, I think, of any serious objection in Evans application to speaking over power lines.

Q. Now, I will ask you to turn for the moment to the Friis patent 1675848, and refer to Figure 1 there. The filter arrangement that is shown as the condenser 13 and coil 14 at the lower right-hand corner of Figure 1, and I will read what the patentee says about it on page 2, line 53. He says:

> "A control current by which the sensitivity of the receiver is regulated is selected from the output of the amplifier-detector 7 by the resonant circuit 13, 14, connected in shunt to its output circuit, which is tuned to the frequency of the intermediate carrier wave."

Now, will you tell us what relation that has to this tendency of a triode detector in such a system to distort the modulation frequency and reduce the contrast?

A. This arrangement of Friis is intended to avoid

the objection that I gave in my preceding answer. Friis' system is a radio system adaptable to broadcast reception and he has taken pains to eliminate this source of distortion. He does that by selecting the carrier from its modulation by the tone circuit 13-14 so that only the pure, unmodulated carrier is used for ultimately providing the automatic volume control potential. In that way the degree of modulation doesn't affect the control and that form of distortion is avoided.

Q. That form of distortion arises out of the use of the triode detector, doesn't it?

A. Yes, it arises out of the use of the triode detector operated as it was then on the square law.

Q. Now, in the Wheeler system, as I understand it, the carrier with the signal,—as I understand it, the whole signal, that is, the carrier with its modulation is impressed on to the diode automatic volume control detector system, is that right?

A. That is true of Wheeler.

Q. And, does he have this difficulty of distortion and if not, why not?

A. No, he does not because that distortion does not occur with the linear detector and the Wheeler arrangement provides for a linear detector in the form of a diode with its high external resistance operated on a suitable signal level.

Q. When you say a high external resistance, you mean high with relation to what?

A. High with relation to the diode itself.

Q. Tell me, Professor, suppose that you undertook to apply the Friis system in which the modulation is separated from the carrier by a resonant circuit, and only the carrier goes to the automatic volume control; suppose you try to apply that to a broadcast radio receiver such as those involved in this litigation; would that provision

for avoiding the distortion due to the triode detector result in any disadvantage in the operation of the radio receiving set?

A. Yes. It would result in a very serious disadvantage. It would result in what is called the double blast; that is, the user would notice that as he was tuning through a station, he would get a loud and harsh response just before he reached the point at which the station was tuned, and then if he passed on, he would get another blast on the other side. So, he would get the two blasts, one after the other, for the reason that the automatic volume control would not function fully except when the station were exactly tuned in so that the carrier was amplified to its full value. But, on each side of that tuning point the signal would still be coming in objectionably strongly, although the automatic volume control would not have begun to function appreciably.

Q. Then, as I understand it, Friis in putting a closely selective circuit, this reasonant circuit, between his amplifier and his automatic volume control, would shut out the control except when the set was closely tuned to the carrier, is that right?

A. That is correct.

Q. And that would result in what you call this double blast from the point of view of the user?

A. Yes.

Q. Now, in the Wheeler arrangement is there any such difficulty as that?

A. No, there is not. Wheeler did not have to select and did not select the carrier alone, so that he did not get the double blast.

Q. I suppose you will agree with Mr. Kelley that this patent to Evans is the closest approximation to the Wheeler patent in existence in the prior art?

A. Yes, I think so.

Q. With relation to the Friis patent, it has the same triode a.v.c. arrangement for producing the a.v.c. potential as Evans has?

A. Yes, essentially the same.

Q. And, in addition to that, Friis has this extra amplifier tube 15 for amplifying the carrier frequency after the modulation has been separated from it, is that right?

A. Yes.

Q. And there is nothing of that kind in the Wheeler system?

A. That is right.

The Court: Mr. Davis, before you leave there, I want to ask a question. While you are on that subject, Professor Hazeltine, will you point out the difference between the Evans circuit and the circuit used by the defendant in their Models 175 and 178. Suppose we take 175 first; that is Exhibit 2-B. And, by the way, Mr. Adams, I will return this original exhibit here to you so that we don't lose it (handing document to Mr. Adams).

A. The basic difference is the use of the triode 8 as a rectifier by Evans, and the use of the diode, which is a portion of the tube 33 in the defendant's Model 175. Associated with that is the use of the plate battery 16 in the Evans patent, which is an isolated battery distinct from the battery 15 for the other tubes.

There is no such isolated battery in the defendant's model, and, in fact, no power source associated with the diode.

There is, also, in the Evans patent the C battery 17, which has no counterpart in the diode arrangement of the defendant's receiver. Quantitatively there would also be the difference in that the resistance 19 in the Evans patent I would take to be of the order of 20,000 ohms, which is the value that Mr. Friis testified as using, and which, as a matter of fact, was in my knowledge, a com-

mon order of magnitude for the impedance in the output circuit of a triode.

In the defendant's Model 175, the corresponding resistance is mainly the resistance 51, which is 500,000 ohms, or some 25 times as high.

There is, a'so, another difference which I haven't referred to before, but which, nevertheless, does indirectly affect the operation that I have discussed. In the Evans patent we have an output transformer 10 in the output circuit of the rectifier. The operation of that rectifier has to be such as to give a suitable audio output and that, in turn, requires a reasonably high plate current; that is, the plate current must not be too near cut-off and must not be too greatly reduced by making the resistance 19 too high.

In the defendant's model there is no such effect, because the output is taken only in the form of a potential; that is, not power but only potential at the arrowhead connected to resistance 51.

I think that covers the most important differences that have to do with automatic volume control.

The Court: I meant to limit the question to the automatic volume control.

Q. Well, now, Professor, with respect to the practical effect, say whether or not in defendant's system as a result of these changes the automatic volume control potential is derived directly from the signal itself?

A. In the defendant's receiver?

Q. Yes.

A. Yes, it is.

Q. Is it possible to derive the potential directly from the signal itself if you use the arrangement of Evans with the triode and its B and C batteries?

A. No, it is not.

Mr. Davis: Now, if your Honor please, I do not want

to hurt your feelings, but I am going to refer to some other patents of the prior art which Mr. Darby did not refer to. That is a rather unusual proceeding, but we feel in this case it is necessary to give a pretty complete picture of the state of the art of automatic volume control. It was a rather peculiar development in that it came about in these years, in the early 20's, and was represented in the work of the engineers in practically every laboratory in the United States. It also should be in your honor's mind, I think, that some of this work was published before Wheeler and some of it was not. For instance, we know now from the Evans patent what Mr. Evans was doing in the Western Electric, but that was not available to Wheeler at that time, and he testified he knew nothing about it. So, you will find that some of these patents that I will mention, I think two of them, were publications available to anyone. The rest of them were represented by pending patent applications which had not been published. I will not trouble your Honor's mind at the moment with any discussion of the legal effect of that. I would like to have you follow this thing just as a factual proposition without that in mind.

Mr. Darby: The patents that you are going to refer to, Mr. Davis, are those on this sheet (indicating)?

Mr. Davis: Yes.

Mr. Darby: Merely for the sake of the record, and preserving my position with respect to them, I object to this testimony as being irrelevant and immaterial to any issue in the case, and then we will subside and not interrupt again.

Mr. Davis: Now, I find after this discussion, your Honor, that I am going to ask Professor Hazeltine to refer first to one of the patents that Mr. Darby did put in.

The Court: All right.

Mr. Davis: Because it is the first chronologically.

Q. (By Mr. Davis): Professor Hazeltine, will you refer to the patent to Affel, 1574780, which was granted to the American Telephone and Telegraph Company, on an application filed on October 5, 1921, and will you tell us as briefly as you can, what sort of an automatic control system is indicated in that patent, and for what purpose?

A. It is, broadly, an automatic amplification control system employing a negative potential on the grid of an amplifier tube, as we have previously been discussing. It is, I think, not strictly an automatic volume control system, because there is no reference anywhere in the specification to any modulation of a signal, and there are references to the use of his system for operating relays, and that sort of thing, so that if we do call it automatic volume control it would be merely as a matter of convenience, thinking of his system as being applied to something which he did not indicate that he contemplated. The system employs a triode rectifier for building up the negative potential. It differs from the patents of Evans and Friis in that the potential is impressed on the triode rectifier as the signal potential before it reaches the controlled amplifier. The latter is the vacuum tube AT in Figure 1. The rectifier being the tube RT. The system has some of the same disadvantages that I have discussed in connection with the Evans patent. That is, it requires a separate battery for the rectifier tube and it requires the same balance between the voltage of that battery and the voltage of the grid bias battery 6.

Q. That is, the control potential is not derived directly from the signal itself?

A. No, it is not. It is derived from the plate battery of the rectifier and is merely controlled by the signal.

Q. And the signal has not been amplified by the con-

trolled amplifier before it is applied to the a.v.c. circuit?

A. No, it has not.

Q. Well, if such a control were applied to a broadcast receiver, that is, the arrangement in which the signal was taken to the a.v.c. circuit before it was amplified in the control amplifiers, what effect would that have?

A. In addition to the effect that the signal might very well be too weak, it would also have a serious effect that it would not be self-controlled, or what is sometimes called self-monitored, which happens in the systems we have considered previously. That is, it is only in case the system is very well adjusted, that it will give the results that are called for in the patent. Those results may be uniform signal level at the output as illustrated in Figure 5. They also may be a non-uniform signal output as illustrated in Figure 8, but it might readily happen that if this were applied in a broadcast receiver and the initial adjustment were not perfect or if the vacuum tube rectifier were changed, that the automatic volume control would be seriously out of adjustment. If the error were in one direction, it might be such that the stronger the incoming signal, the weaker would be the reproduced signal, or if it were in the other direction, the result might be that the reproduced signal would not be controlled nearly as much as was desired. That sort of thing does not occur in the automatic volume control of Friis or Evans or Wheeler or in the defendant's apparatus.

Mr. Davis: Now, if your Honor please, that patent had not been published at the time of Wheeler's invention, although it was filed in 1921. Now, I am going to turn to a patent which had been published at the time of Wheeler's invention.

The Court: All right.

Q. (By Mr. Davis): Will you direct your attention, Professor, to the patent to Espenschied and Bown, number 1447773, granted to the American Telephone & Telegraph Company on application filed September 15, 1921, the patent issuing on March 6, 1923, and will you refer to Figure 1 of that patent and tell us as briefly as you can what the automatic volume control system is?

A. In this automatic volume control system the use of a grid potential control does not appear. What is done is that the detector tube D puts a direct current through two relay windings, R-1 and R-2, that direct current being affected by the received signal, as we have discussed in the other systems, but here that current is used to operate those two relays, which in turn operate other relays so as to cause a motor to turn in one direction or the other in accordance with the strength of the rectified signal current. The motor operates an arm 13 connected to a resistance 12 by an arrangement often called a potentiometer. The result is that a fraction only of the received signal at the output of transformer 9 is impressed on the grid. The stronger the incoming signal the smaller will be that fraction.

Q. By the way, Professor, is there in this patent a good description of the detector operation with reference to Figure 2 of the drawing, and if so, will you indicate where it is?

A. Yes, there is an excellent and at the same time brief description of the behavior of the detector, and that begins on page 1, line 92.

Q. That is a generalized description of the action of a three-electrode detector?

A. Yes, and operating over the range that we have discussed for a three-electrode detector, that is, over a range where the operation is substantially of the square-law variety, as is illustrated in his Figure 2 and explained in this paragraph.

Q. Now, I observe that in Figure 3 of this patent there is use made of a three-electrode tube connected as a diode, that is, with the plate and grid connected together, is that right?

A. No, not quite, I think. It is a tube having two plates which are connected together. The effect, of course, is the same.

Q. It is a diode and not a triode?

A. It is a diode, yes, sir.

Q. Will you tell us what that diode is used for?

A. That diode is the rectifier used for automatic volume control. In this case he has a modification in which he puts a control frequency in his signal and then filters out that control frequency, and impresses that alone on the diode rectifier. This, like the preceding case is not a potential producing device. The rectifier operates a relay by sending a current through its winding and it is a current producing or power producing device. The rest of the apparatus is essentially the same as in Figure 1.

Q. This control frequency that is put into the system is sometimes called a pilot wave?

A. Yes, he refers to it as a pilot wave, I think, in the patent.

Q. You heard Mr. Wheeler testify that in one of the arrangements that he worked out in his notebook he used a pilot wave?

A. Yes, in this same sense.

Q. And you say that this diode is used as a current producing or power producing device. Has it any high resistance in its circuit?

A. No, it has not.

Q. Would high resistance in its circuit defeat the power-production effect?

A. Yes, it would. It would be difficult to get a really

high resistance in the magnet, but in any case the purpose is much better achieved by using only a moderate resistance, that is, a very low resistance in comparison with this which we have been considering before as high resistances.

Q. Now, will you turn to the Affel patent 1468687, which was granted to the American Telephone & Telegraph Company on an application filed May 4, 1922. I call the Court's attention to the fact that in this patent the issue date was September, 1923. That was an issued patent before Mr. Wheeler's invention. Will you refer, Professor, to the diagram of that patent and tell us what sort of an automatic volume control system it is?

A. I think I might refer to Figure 1 as being representative. It has in common with the Espenschied and Bown patent previously discussed the use of relays and a motor and a potentiometer type resistance. The first relay is the one marked PR at the right, and then there are relays 18 and 19 below. They connect to the motor. And the potentiometer resistance is 14, on which moves the arm 15. That much of it is like Espenschied and Bown. The difference that is most essential for our present purposes, is probably the fact that Affel sharply selects his carrier. That is done in the circuit marked 12 which includes a coil and condenser and which he refers to as a tuned circuit or filter, so that his rectifier R receives only the pure unmodulated carrier.

There are certain other differences, however, that must be mentioned. He controls the potential impressed on the detector here, which is the tube D, and that detector delivers in its output circuit both the original carrier and also a lower frequency which is to be passed on. That is the usual detected signal. And, quite unusually he passed on these two components together

through the amplifier marked RA, and does not separate them until he gets to the output circuit of that amplifier; the signal then going on through what is marked LPF, meaning low pass filter, and the carrier going through the tuned circuit 12, as I have mentioned.

Q. He used the triode rectifier with the B battery and C battery?

A. That is correct, and with the tuned circuit that would give the double blast effect which I explained previously in connection with the Friis patent.

Q. Is the control effected by varying the amplification by grid bias or otherwise?

A. Otherwise. By this potentiometer resistance as in Espenschied and Bown.

Q. Mr. Kelley has told us who Mr. Affel was, Professor. Do you know who Espenschied and Bown were?

A. Espenschied and Bown are prominent engineers of the American Telephone & Telegraph Company. Dr. Bown has been president of the Institute of Radio Engineers, and Mr. Espenschied has been very active in that Institute for a great many years.

Q. Now, I wish you would look at the two Affel patents number 1511014 and 1511015, granted to the American Telephone & Telegraph Company on applications filed May 4, 1922; the patents issuing in 1924, and I will ask you to look at the second one first, that is the 1511015, and tell us about that, referring to the diagram Figure 1?

A. That diagram, except for the strictly automatic volume control arrangement, is like the arrangements of the Affel patent which I last discussed. That is, he has a detector which passes on both the carrier and the detected signal, the two components being separated after passing through the amplifier RA as before. And the carrier is then selected out sharply in the tuned circuit

12, and is then rectified in the rectifier R. So far that is just exactly the same arrangement as in the patent previously discussed, but now Affel takes the output of the rectifier R and uses it to build up a potential in the resistance 14, the connections being shown clearly by heavy lines, and that potential in resistance 14 is impressed on the grid of his detector tube D, so as to control the detecting efficiency.

It should be mentioned that the arrangement as shown is defective in that the output of rectifier R would contain components of the original carrier, and they would be impressed on the input circuit of detector D together with the direct current. That is, there has been no filtering out of the carrier, and that would cause this system to generate local oscillations which would really make it inoperative as it stands.

Q. Now, will you refer to the patent 1511014 and tell us about that?

A. This has automatic volume control systems quite different from those that we have had to consider previously. In Figure 1 there is a separation of the carrier from the modulation side frequencies in the circuit marked 11. That circuit is a transformer connected through a condenser across the wires where the signal is coming in. The signal is coming in to the box marked BF-2 or band filter. Then the carrier alone is put through the vacuum tube 12 which has what is called limiting action. That is, so long as the carrier is above a certain low strength, the output of that tube at the same carrier frequency will be held constant. After having separated the carrier from the modulation side frequencies, Affel again puts them together in a complicated detector system marked D-2 involving two vacuum tubes, and he has, therefore, ended up by keeping his received carrier constant although the modulation components will vary.

In Figure 2 he still has a variation in those modulation components, but this time he tries to compensate for them by making the carrier itself become weaker on the output side of the tube 12, as it becomes stronger on the input side, and so he will get a tendency toward a constant reproduced signal by having his carrier go down when the side frequencies go up in intensity.

Q. In these systems that you have described, in each of them he uses a three-electrode detector for the automatic volume control?

A. That is correct.

Q. Now, will you look at Figure 3, where I believe he uses two diodes, and say whether they are used to rectify?

A. They are used to rectify individually, but not because he really wants rectification. What he really wants is an S-shaped characteristic curve connecting current and voltage which is shown immediately above in Figure 3-a, and the easiest way to get that is the combination of two diode curves. He has here also a system quite different from the rest of those in this patent, and from anything else that we find, it depending merely on this peculiar shape of the characteristic curve. That system is not wholly operative as it stands, but the principle could be applied if it were worthwhile doing so.

Q. Are these systems of Affel's in this patent directly applicable to high frequency, that is, to radio frequency?

A. Those that I have explained so far are not, as Affel says, but in Figure 4 he shows a system which is a radio receiver, and in which he takes the received high frequency and steps it down by a heterodyne arrangement before he applies his automatic volume control. He recognizes that the relations that he wants, the

tuning to the carrier could not conveniently be carried out effectively at the high radio frequencies, but require lower frequencies for their proper operation.

Detroit, Michigan,
Thursday, November 2, 1939,
9:00 o'clock A. M.

Court met pursuant to adjournment.

LOUIS ALAN HAZELTINE, was thereupon recalled as a witness, having been previously duly sworn, testified further as follows:

Direct Examination (Continued)

By Mr. Davis:

Q. Professor Hazeltine, I want to complete the discussion of the patents of Affel before going to the patents of others, so I will ask you to turn to the Affel patent 1677224, granted in July, 1928, to the American Telephone & Telegraph Company, on an application filed March 23, 1926. Will you please tell us about that Affel automatic volume control system and how it is related to the preceding ones that you have discussed?

A. This Affel system may be considered as combining the arrangement of the Affel patent 1511014, and the arrangement of the Affel patent 1511015. That is, in the latter Affel patent the carrier is filtered out from its side frequencies and is put through a limiter tube, indicated by "10" in Figure 1. At the same time, in a branch circuit, 8, the carrier is also rectified in a triode rectifier; and the rectified current builds up a potential

for control of the detecting efficiency of the pair of detector tubes here called "demodulator" and numbered 13.

Q. Let me interrupt you there, Professor. That is, in this Affel arrangement the control is applied not to the amplifying tubes but to the detector tubes, is that right?

A. That is correct. That was also true of the two prior Affel patents to which I have just referred.

There is a further peculiarity in the application of the control potential to the grids of the detectors in that the stronger the signal the more positive the grids become. This is permissible in controlling a detector, but would not be feasible in controlling an amplifier in which the grid is invariably made more negative as the signal becomes stronger.

This Affel patent, like the two preceding ones, has the disadvantage inherent with a sharp selection of the carrier, that is, it has the disadvantage of giving the double blast while the user of the receiver is tuning through a station. It also has the disadvantages inherent in the triode detector or rectifier, of requiring extra batteries and requiring a critical adjustment of the B voltage and the C voltage.

Q. You say that this control in the positive direction, that is by putting a positive bias on the grid, although applicable to a detector, would not be applicable to an amplifier. Can you tell us what effect it would have on the amplifier; that is why it wouldn't be applicable.

A. Under ordinary conditions the control would be in the wrong direction. That is, the stronger the signal, the greater would be the degree of amplification, just the opposite effect to that desired. Under extreme conditions in which the amplifier was overloaded, there might be some tendency towards automatic volume control, but

only at the expense of prohibitive distortion. Such effects occur when the grid becomes positive, so that the current will flow in the grid circuit.

Q. I notice that in the specification of this Affel patent he speaks of providing a pilot frequency transmitted from the sending station, I think. Will you say a word about what that means? I am looking at the third column of page one, about line 18.

A. Sometimes the expression "pilot frequency" is used to indicate an additional frequency in the form of a modulation; but, sometimes it is used to refer to the carrier itself, and here the reference is to the latter; that is, he says:

"Sufficient carrier current is permitted to flow into the transmitting antenna circuit to provide a pilot frequency which is used in the receiving circuit as a means of stablizing the output thereat."

It here refers simply to the carrier itself.

Q. Now, will you turn to the patent to Ohl, number 1772517, granted in 1930 to the American Telephone & Telegraph Company, on an application filed February 20, 1926, and tell us what system of automatic volume control is disclosed there, and how it is related to the Affel system that you have been discussing?

A. This system may be considered an extension and refinement of the Affel patent number 1511015. In fact, the patentee, Ohl, refers to this Affel patent, in the second paragraph of the specification, and points out that the Affel arrangement produces the likelihood of singing in the system, which means the production of a local oscillation, as I mentioned yesterday in my testimony. The arrangement of Ohl is conspicious in very sharply selecting the carrier from its side frequencies or modulation components. This is done by the element 10 in Figure 1 marked "Quartz crystal." The quartz

crystal has conspicously the so-called piezo-electric effect, which means that a varying voltage impressed across it will set up mechanical stresses and cause it to vibrate in unison with varying voltages.

Q. Well, that is the "means new in this connection for selecting more sharply that has been done heretofore the carrier frequency component which is to be rectified and impressed upon the detector to effect the desired variation of grid potential," is that right?

A. That is right, because the quartz crystal can be tuned more sharply than any simple electric circuit.

Q. Well, you have spoken in your testimony of this selective circuit to separate the carrier from the modulation in connection with the Friis patent, and with the patents of Affel that you have discussed, is that right?

A. Yes.

Q. And this is an improved, more refined way of doing that same thing?

A. It is more refined, but it would accentuate the disadvantage of such systems in producing the double blast.

Q. Now, will you look at the patent to Falknor, number 1698014, granted in 1929 to the Westinghouse Electric & Manufacturing Company, on an application filed March 13, 1924, and tell us what kind of an automatic volume control system is disclosed in that patent?

A. This is an automatic volume control system entirely different from any that we have previously encountered here. It is an elaborate arrangement involving two receiving antennas which here are of the form of coils, number 1 and 21.

The signal which is finally reproduced is received on the coil aerial or antenna 1. At the same time the signal is received on the other coil aerial 21. The signal detector is the tube 2 and that is a regenerative detector in which

radio frequency components of the output current are used to reinforce the incoming signal by the regenerative or feed-back principle due to the coupling between the two coils 5.

The idea of Falkner is to vary the effectiveness of that regenerative coupling by shunting the output circuit of tube 31 across one of the coils 5, and causing the effectiveness of that shunt to vary with the signal strength as received in the detector tube 22 and passed on to the tube 31. This system, therefore, has nothing of the grid bias feature that is present in the patent in suit, and is quite unlike any of the other arrangements that we have seen.

Q. Does the grid condenser 3 and the grid leak resistance 4 take part in this regenerative operation?

A. Not directly. They make the tube 2 a detector, but they do not take part in any way in the automatic volume control.

Q. Now, will you turn to the patent of DeBellescize, 1867139, granted in 1932 to the Radio Corporation of America, on an application filed March 30, 1927, and tell us what kind of automatic volume control system is disclosed in that patent?

A. This automatic volume control system employs a varying bias potential on the grid of an amplifier tube. But, the variations in this potential are produced through the inter-position of a mechanical relay instead of being produced from some rectified current flowing through a resistance.

Q. That mechanical relay controls the output from the battery 6; is that right?

A. Yes. And, in two of the figures, there is also a battery 5. In those latter figures a switch is thrown over from battery 5 to battery 6 whenever the signal is to

be controlled in one direction, and is thrown back when it is to be controlled in the other direction.

Q. That is, in this Radio Corporation arrangement the signal does not itself produce the control potential but acts through a mechanical relay to control the potential supplied by a local battery, is that right?

A. That is right.

Q. Will you look at the patent to Bruce, 1778750, granted in 1930 to the Bell Telephone Laboratories on an application filed December 31, 1926, and tell us what sort of a system of automatic volume control is disclosed in that patent?

A. This brings us back more to the systems that we first had to consider in that a rectifier tube is used to build up a direct current potential in a resistance which will be the greater the stronger the received signal. In the Bruce arrangement, however, this control is applied to a super-heterodyne receiver only, and is impressed on the grid of a tube which he calls the first detector, but which is, perhaps, better called the modulator tube, or the converter tube. That is the tube indicated by D in Figure 1.

In Figure 2 he has a so-called double super-heterodyne in which there are two successive reductions in frequency, and he applied his control to each of the modulator tubes, which are 4 and 22.

The rectifier tube which Bruce employs is the triode, and that, of course, entails all the usual objections to a triode.

Q. That is triode 15 in the two figures?

A. That is right.

Q. Now, will you look at the patent to Simonds, 1914219, granted in 1933 to the General Electric Company on an application filed January 3, 1927, and tell us what sort of automobile volume control is disclosed in that patent?

A. This, again, has an automatic volume control arrangement in which the amplifier grids are biased by a potential built up in a resistance in proportion to the strength of the detected signal. The characteristic feature of this patent, however, is that a so-called direct current amplifier is inserted between the rectifier and the controlled grids. That direct current amplifier is the tube 43 together with its associated batteries and resistances which are toward the bottom of Figure 1. The rectifier tube is the tube whose filament and grids are marked 21 and 11, in the upper middle of the figure. This arrangement involves additional batteries both in connection with the direct current amplifier and in connection with the rectifier.

Q. At the risk of some repetition, Professor, I am going to ask you to tell us in this system where the energy comes from that supplies the automatic volume control biasing potential and how that is related to the energy of the incoming signal itself?

A. The energy which provides the biasing potential comes from the local battery which is here a part of the battery 27. That battery is controlled by the signal amplified in the tube 43. But that signal received in the tube 43 is a rectified signal which has its energy derived also from a local battery in the plate circuit of the detector or rectifier tube, so that here there are successively the interposition of two sources of energy between the high frequency received signal and the desired control potential.

Q. Each of those interposed sources being controlled by the amplifying action of a three-electrode tube, is that right?

A. That is right.

Q. Will you look at the patent to Carter, number 1739351, granted in 1929 to the General Electric Company on an application filed January 14, 1927, and tell

us what sort of an automatic volume control system is proposed in that patent?

A. This is a system differing essentially from any that we have considered previously. A vacuum tube of the triode form is shunted across one of the tuned circuits, and that tube, which is marked 21 in all of the figures, has its resistance controlled by a potential on its grid, which, in turn, depends on the strength of the received signal. The effect of the shunting of this tube across the circuit is partly to put an additional load on the circuit and so weaken the signal, and is also partly effective in changing the tuning of the circuit. The potential that controls this loading tube 21, is derived from a rectifier tube which may either be a diode, as tube 11 in Figure 1, or else, as is preferred by the patentee, it may be a triode tube, which is the signal detector 4, in Figures 2 and 3.

Q. In what direction is the bias varied in order to control the loading effect of this tube?

A. The stronger the signal, the more positive is the bias potential in order to increase the shunting action of the tube. That, of course, is in the opposite direction to that used with the grid bias control in the Wheeler patent and in other patents using that feature.

Mr. Davis: That completes, if your Honor please, the patents we desired to put before you that show other systems of automatic volume control, and I am going to turn now, briefly I hope, to some of the patents showing various uses of diodes that were discussed in the defendant's case, and first I will ask you, Professor Hazeltine, to refer to the patent to Slepian, 1455768, and first I will ask you whether that patent shows an automatic volume control system?

A. No, it does not.

Q. Will you tell us what it does show?

A. The patent shows a form of super-regenerative receiver designed to make the response proportional to the received signal, which is just the opposite condition to that desired in automatic volume control.

Q. Let me interrupt you. Will you say whether or not that is the condition desired in an ordinary amplifier?

A. Yes, that is exactly the condition called for in an ordinary amplifier.

Q. That is, as I understand it, amplification is defined as the reproduction in the output circuit of a form of energy which corresponds in form to the input energy, but is larger in amplitude?

A. That is correct.

Q. Is that what Slepian does?

A. Yes, that he states particularly on page 2, beginning line 31, as follows: "It is desired to so adjust the system that if a certain signal-current brings the intermittent oscillations up to their full amplitude, a smaller signal-current will give intermittent oscillations of smaller amplitude, and so, on continuously, to infinitesimal amplitude." These local oscillations, or intermittent oscillations that he refers to, are reproduced proportionately in the telephone receiver 11, so what he says about the intermittent oscillations also applies to the ultimate reproduced sound.

Q. Now, will you tell us how these intermittent oscillations are produced in this system?

A. The intermittent oscillations are produced even though the characteristic feature of this invention is absent. That is explained quite correctly by the patentee in the first column of the patent toward the bottom. It was a fact that was long known and its reasons were also known, that a regenerative vacuum tube having a grid leak and condenser, when so adjusted as to actually produce an oscillation, was prone to have that oscillation

broken up into groups giving the intermittent oscillations which are made use of in this patent.

Q. Let me interrupt you, Professor. At this point will you tell us where the energy comes from that is thus made to appear in the system in the form of intermittent oscillations?

A. This energy comes from the battery 12 in the plate circuit of the detector tube 1.

Q. And before you go on I will ask you this; is there any such arrangement of the grid leak in the automatic volume control systems that we have been discussing like Wheeler's?

A. Oh, no, there is nothing of that sort nor is there any production of the local oscillations.

Q. There is no regenerative feature?

A. No. Such effects have to be very carefully avoided in the modern types of receiver.

Q. Now, will you go ahead and explain how this grid leak arrangement produces these oscillations and how Slepian proposed to control them to produce amplification?

A. As Slepian described in the paragraph beginning on page 1, line 28, the oscillations would be produced even in the absence of the diode, and would be broken up into groups as I described. The effect is this: if the regenerative control between coils 15 and 7 is strong enough to produce oscillations at all, then those oscillations will be rectified in the grid circuit, and the rectified oscillations will build up a negative potential in the resistance 9, which is the grid leak, and the condenser 8 in parallel with it.

The oscillations after they have once been started, will continue to increase for a time until the negative potential attained by the grid is sufficient to block them, that is, to very greatly reduce or destroy the amplifying ac-

tion or relay action of the tube 1; and the oscillations will then not start in again until the condenser 8 has time to sufficiently discharge itself through the resistance 9.

All that is an old effect well known long before the period in question.

Now, Slepian adds to this system a diode tube 18, which is in essentially the same place as the grid and filament 3 and 4 of tube 1, but which receives a somewhat higher voltage than is received by the grid 3. That is, the coil 16 connected to the diode develops a somewhat higher voltage than the coil 7 connected to the grid 3.

The diode, therefore, takes over the action that would otherwise be taken by the grid. That is, the diode does the rectifying of the oscillation and builds up the potential across the condenser 8; and the grid 3 no longer is called on to give that rectifying effect.

Now, the idea which Slepian has here and which he explains as appearing, "most plausible" those words occurring on page 2, line 27—is that the local oscillations will be built up more rapidly, and therefore to a higher intensity, the stronger the received signal which sets them off. That is, these local oscillations are supposed not to occur in the absence of a signal, but to be triggered off by an incoming signal which is impressed in the same system of coils where the oscillation is regenerated. And, he wants the strong signal to produce a strong local oscillation, and a weak signal to produce a weak local oscillation. Those oscillations are represented in Figure 3 where the oscillation is weak, and in Figure 4 where it is strong. The high frequency oscillation is represented by the very wavy line in Figures 3 and 4 and the mean value of the oscillation is represented by the smoother line that runs through the waves. In both

cases the waves represent grid potential. The smoother line represents the effective average grid potential throughout one of the oscillations, and that is the quantity which controls the current in the plate circuit which passes through the telephone receiver 11. So that, with a weak signal, the telephone receiver will get a small pulse of current, and with a strong signal it will get a large pulse of current.

Now, these pulses occur in the case of undamped telegraph signals, which are first referred to in the patent, at an audible rate. That is, this intermittent effect may occur one thousand times a second and thereby produce a thousand pulses per second in the telephone receiver, and cause the receiver to emit a note having a frequency then of a thousand cycles per second.

Q. That is sort of a whistling note, isn't it?

A. Yes.

Q. Will you proceed?

A. And the main point there is then that the patentee wants that note to be strong for large signals and weaker for weak signals.

He also contemplates as another use of his invention, which is referred to secondly, beginning line 104 on page 2. He contemplates using this for telephone reception, in which case the oscillations will have to be broken up not at one thousand cycles per second, but at a frequency which is above the audible range. In that case, of course, the proportionality between the received signal and the strength of the oscillations is absolutely essential, because otherwise the response would be completely distorted.

Q. Say whether or not in this amplifier of Slepian's, if it worked the way he describes, a signal which had a strong carrier wave and was modulated, would be reproduced as a strong modulated signal in the receiver?

A. Yes, it would. That is essential to his mode of operation.

Q. And a signal which had a weak carrier as received at the receiving set would be produced as a weak signal?

A. That is correct.

Q. And, is there any arrangement in this patent for putting an upper limit on the volume of the sound produced by the amplifier?

A. No. That is not part of this system.

Q. Mr. Kelley, in answer to a question of Mr. Darby's, said that in this system the diode was coupled to the output circuit of the amplifier. That much is true, isn't it?

A. Yes. It is coupled to the output circuit and also to the input circuit. All of those circuits are coupled together, as I mentioned.

Q. And, it is by that coupling to the input circuit, that the regenerative effect is produced, is it not?

A. Yes, that is necessary.

Q. And, if you couple the output circuit of the amplifier in these radio receiving sets such as Wheeler's and the defendant's back to the input circuit, what would happen?

A. They would go into oscillation and would prevent the proper operation of the set. The listener would just hear a loud whistle and not the signal that he wanted.

Q. And what you just said is another way of saying perhaps what you pointed out in connection with the defect in the Affel system, that lets part of the radio frequency energy go back on the control circuit to the control grid and thereby produce a regenerative action?

A. That is correct.

Q. Now, will you turn to the patent to Heising, which also uses a diode, and tell us, please, what that diode is used for?

A. That diode is used primarily to improve the efficiency of a telephone transmitting system which has no carrier. That is a special kind of telephone transmitting system in which the carrier, after being modulated, is itself eliminated from the system, leaving only its side frequencies for subsequent amplification and radiation through an antenna. Heising wishes to improve the efficiency of the power tubes, which are the tubes 4, and which have a large amount of power to handle, and in which the loss of power, due to lowering efficiency, would be serious; and he recognizes that systems which he had previously proposed for other power amplifier tubes would not be applicable to this particular system in which the carrier was suppressed. He realized that what he would normally do, that is, permanently bias the grids to a relatively high degree, would not be applicable because then weak modulation would not be amplified at all. He also recognized that the ordinary amplification arrangements would give him a different degree of amplification for weak modulation and for strong modulation, the amplification actually being better for the strong modulation. So he not only attempts to improve efficiency, but he also attempts to reduce the distortion that is consequent on this ordinary unequal degree of amplification. His system then employs the diode 11 as a rectifier tube to provide a continually varying bias potential on the grids of his power amplifier tubes 4 in such a way that the amplification becomes uniform for different intensities of modulation.

This then improves the efficiency of the system, and at the same time reduces the distortion.

Q. Is there any automatic volume control in this system?

A. No, not at all. It is necessary in this system that the output of the power tubes follow the input, the

stronger the input the stronger the output; and his system gives that result and that is just opposite to the result of automatic volume control.

Q. I brought out in cross examining Mr. Kelley yesterday that in this system the potential that the rectifier impresses on the amplifier grid is a potential that varies at a frequency twice the modulating frequency, is that right?

A. Yes, that is correct, and the patentee says that this is one of the important features of his invention, that statement being made on line 80 of page 3.

Q. And this feature is also referred to in the patent on page 2, beginning line 68 and running down to about 78, is that right?

A. Yes, that is correct. And, he points out that this feature can be produced not only by the arrangement of Figure 1, but by a totally different arrangement in Figure 5; and that is effective for his purposes, but does not employ the diode 11, or anything corresponding to it.

Q. Would this system be applicable to broadcast reception?

A. Oh, not at all. In broadcast reception, it is necessary to use a bias which is a pure direct current potential, and with Heising it is necessary to employ this varying bias.

Q. Now, will you refer to the Armstrong patent, 1716573. I questioned Mr. Kelley yesterday about this patent and he agreed with me that in the diode and resistance arranged to give linear detection, was not used in connection with automatic volume control, but when I asked him whether the Armstrong arrangement was one in which the output of the detector was used in the form of current or in the form of potential, we could not come quite to an agreement on that. Will you please explain that?

A. Referring to Figure 5, which shows the diode detectors, 55 and 54, the output is produced in the transformers 61 and 60, at the bottom of the figure, and is led to the telephone receiver, 62. Of course, the transformer is a power device in the sense that it requires both voltage and current, and unless the tubes were delivering a suitable strength of current, the telephone receivers could not be actuated. So, the arrangement is not simply a potential producing arrangement, but it is an arrangement for delivering current.

Q. And state whether or not the resistance which is in series that is the resistance 52 and 53, tends to limit that current?

A. They do. They are not part of the output circuit. They are, so far as this arrangement is concerned, a necessary evil. They do give linearity, but they waste power that could otherwise be delivered to the telephone receiver.

Q. Are you personally acquainted with the work that Major Armstrong did with this type of static elimination system, and do you know whether he subsequently modified it in practical application?

A. Yes, he did. I attended a meeting at which he described this system as subsequently modified, and he modified it in such a way as to make use of the potentials in resistances 53 and 52, instead of using the transformer arrangement that is shown in the Figure 5 of the patent.

Q. Was that modification before or after the publication of Mr. Wheeler's invention in his paper read before the Institute of Radio Engineers?

A. The paper of Armstrong was published in the same issue of the proceedings as the paper of Wheeler. The Armstrong paper was delivered one month before the Wheeler paper, if I remember correctly.

The Court: Before you go to the next patent, I think

I will excuse you for a few minutes here and that will allow me to take care of another matter.

(A recess was thereupon taken).

Q. (By Mr. Davis): Now, Professor Hazeltine, will you please turn to the Schelleng patent, 1836556. Is that an automatic volume control system?

A. No, not at all.

Q. It shows the use of two diodes, but in what kind of a system?

A. This is a safety system designed to prevent an output voltage from rising above a safe value. It is, therefore, analogous to a lightning arrester or in the mechanical field, to a safety valve for a steam boiler.

Q. Is it shown applied to the amplifier in a radio transmitting system?

A. That is correct.

Q. Now, will you go ahead and tell us as briefly as you can how that safety device works?

A. The purpose of the safety device is to shunt a load across the input of the amplifier which is between the grid and filament of the tube 3. That load which is shunted across is the diode 19. The way in which it is done is this: when the excessive voltage appears in the output circuit, that voltage will be impressed in part on the diode 9. It is rectified there and produces a corresponding increase in the current through the resistance 18, and therefore an increase in the potential difference developed in that resistance. Before the voltage becomes excessive, the potential difference across the resistance 18 is less than the voltage across battery 20, so that the combination of those two voltages makes the mode of 19 negative, and when it is negative it cannot attract electrons, and so the tube 19 acts as an open circuit. In other words, it is just as if it were not there.

But when the excessive voltage comes in, the anode is

made to be positive, the voltage of 18 then exceeding the voltage of 20. As soon as the anode becomes positive the tube acts as a partial short circuit to the input, and so reduces the input to the amplifier and prevents that excessive voltage from being developed at its output circuit.

Q. If such a diversion were applied to a broadcast receiving system, that is, such as we are discussing here, a diversion of part of the current from the input circuit through such a shunt circuit as proposed in Schelleng's amplifier safety device, what effect, if any, would it have on the operation of the system?

A. It would cause a distortion of the signal.

Q. Is there any control of the amplification in this Schelleng system?

A. Not as we have understood the control of amplification; no, sir.

Q. It simply cuts off part of the signal so that it doesn't get to the amplifier, is that right?

A. That is correct.

Q. Professor, will you please turn now to the circuit diagrams of the defendant's accused receiving sets, that is, Exhibits 2-B and 3-B. I guess you can't turn to them both at the same time, so I will ask you to turn to Exhibit 2-B first.

Q. Professor Hazeltine, on your examination the other day you described to us the defendant's automatic volume control arrangement as shown on these circuit diagrams, Exhibits 2-B and 3-B, and traced the circuits, and I then asked you, or then read to you from the patent, the Wheeler patent, the paragraph that begins in line 12 of the second column of page 2, which paragraph begins with the words: "In accordance with the main feature of the present invention", and so on, and you testified that that paragraph correctly describes the defendant's systems in each of the two sets. You

have heard the testimony of Mr. Kelley in which he referred to these automatic volume control circuits in the defendant's set, and pointed out certain differences between that circuit and the automatic volume control circuit of the Wheeler patent, did you?

A. Yes.

Q. Did that testimony cause you to modify in any way the assertion or would it cause you to modify the assertion you made that the paragraph I read from the Wheeler patent correctly describes the defendant's systems?

A. No, I would not modify my statements. I think they were entirely correct.

Q. And are you still of the opinion that the defendant's sets contain each and all of those elements which Wheeler there describes as the main feature of his invention, is that right?

A. Yes, sir.

Q. Now, will you discuss first the circuit of Model 175, Exhibit 2-B, making reference to the differences that Mr. Kelley referred to, and particularly first the difference in the position of the condenser marked 2. Tell us how that affects the automatic volume control system, in detail?

A. In both the Wheeler patent and in the defendant's receivers, the signal voltage is developed across a tuned circuit consisting of the coil, 31, and an associated tuning condenser. It is necessary to impress that voltage between the anode and cathode of a diode, but it is also necessary not to make a direct connection there. It is necessary to make a connection through a condenser. That condenser then may be in either of two alternative positions: it may be next to the anode as in the Wheeler patent or it may be next to the cathode, as in the defendant's receiver. Arrangements of this

sort, the connection of a tuned circuit to a vacuum tube or other detector, were of course very common for other purposes before this invention, and it was very common to use either one or the other of those two alternatives. I myself have used them both years before this invention. So that there is no difference up to the present point in the discussion as to whether that condenser be on one side or the other of the diode.

There is, however, some difference in detail in the two connections when we consider particularly the connection of the high resistance. Again we have two alternatives, analogous alternatives which were also well known long before this invention, for other purposes. One arrangement for this high resistance is to have it connected from the anode to the cathode of the vacuum tube. That is the arrangement of 51 in the Wheeler patent. The other alternative is to have the resistance 51 connected across the condenser 2. The reason for one or the other depends on certain limitations, or certain desirable features that may be different under different circumstances. Wheeler in his patent chose the arrangement that is most suitable under the circumstances that existed with the apparatus shown. Those circumstances may seem somewhat trivial. They required the tuning condenser, 32, to be grounded on one side, and it was also desirable to have the coil directly connected to the condenser so that became grounded on one side. The cathode or filament, 38, being desirably grounded, it was necessary to have the cathode and the condenser connected directly together.

Those limitations finally resulted in the desirability of having resistance 51 between the anode and cathode. All of that came largely from the fact that the tubes that Wheeler had were of the filament type, not the indirectly heated type used now. Also, the fact that the

set of the Wheeler patent was of the tuned radio frequency type requiring a condenser adjustable by the user influenced the engineering decision on this point.

Those limitations are not present in the defendant's apparatus, and, therefore, they have chosen the other alternative of connecting the resistance 51 across the condenser 2. That arrangement is actually preferable where it is permissible because it simplifies the filtering out of the carrier frequencies, that is the carrier itself and the modulation components present in the carrier.

Q. Let me interrupt you there a minute, Professor. You say that is actually preferable where it is permissible, and I understand it is permissible in a super-heterodyne system using indirectly heated filaments such as in the defendant's sets, is that right?

A. Yes, that is right.

Q. But not permissible for the reasons you have already stated in the tuned radio frequency set with an adjustable condenser?

A. That is right.

Q. Now, will you proceed?

A. The resistance 51, therefore, of the Wheeler patent received across it the full value of high frequency signal potential, and that necessitated a relatively powerful filter for high frequencies; so that in the Wheeler patent the resistance 34 and the condenser 37 constituted this radio frequency filter, and it was necessary to make a powerful filter by making resistance 34 relatively large as Wheeler did.

In the defendant's apparatus the resistance 51 being in parallel with the condenser 2 received only very little of the high frequency signal because the high frequency signal current could pass through condenser 2 with very little opposition. So that, the necessity for a powerful filter was not present.

This filter in the Wheeler patent is referred to as a rejector circuit. In the defendant's apparatus the condenser 2 itself is largely a rejector. However, the defendant's receiver, Model 175 as well as Model 178, have a refinement: that is, they have, in effect, a second stage of radio frequency filter or rejector.

Q. Let me interrupt you a moment. Before you go to that, I would like to have you say whether or not the rejector circuit in any form is included in that description from the Wheeler patent that I read to you of the main feature of his invention?

A. No. That is not mentioned in that paragraph. And it is not, in fact, a main feature of the invention.

Q. Now, will you proceed to describe this refinement you started on?

A. This refinement includes the resistance marked 34 on Exhibits 2-B and 3-B, that being the nearest analogue of the 34 of the Wheeler patent. Associated with that must be, of course, a capacity and a comparatively small capacity is necessary for the filtering action at the high signal frequencies, that is the radio frequencies, because these frequencies are so high. And, that capacity is afforded by the natural capacity of the connections to the point 52. It will be seen that at the point 52 we have connections going in four directions, connecting to four different resistances, up and down and right and left; and particularly the resistance which is marked R-12, which is a variable resistance used for tone control, is arranged physically in such a way as to have a very appreciable capacity to ground. So that the combination of that capacity, which we can only make general estimates of, and the resistance 34, whose value we know, would be sufficient to give an appreciable and desirable additional filtering or rejector action at radio frequencies.

Q. As I understand it, the higher the frequency that

is to be rejected, the smaller the capacity needed to reject it becomes?

A. That is correct.

Q. In the defendant's sets in both cases the resistance 34 is a separate physical resistance from the resistance 51, isn't it?

A. Yes, that is true.

Q. And the direct current connection back to the grid is taken off from between them?

A. That is correct.

Q. State whether or not the automatic volume control potentials in those systems is developed across the resistance 51 alone, or across the two resistances?

A. There is a potential developed across the two resistances, but only that part of it which is developed across 51 is used for automatic volume control. The ratio of the two resistances being 10 to 1. That means that the resistance 51 has 91 per cent of the total developed direct current potential so that the loss in 34 of 9 per cent is evidently not of any importance.

Q. Is there any other function or reason for separating the resistance 34 from the resistance 51 and connecting the direct current connection between them, than the function of serving as a refined rejector circuit?

A. No, I can think of no other reason.

Q. Mr. Kelley mentioned the fact that the actual value of the resistance 34 in the defendant's sets was, I think, only 50,000 ohms, whereas the resistance 34 in the Wheeler patent is given as a million ohms. Now, will you discuss that?

A. I have already given the reason for that. In the Wheeler patent it was necessary to have a powerful filtering action because of the high radio frequency potential across resistance 51, and he had to use, therefore, a relatively high resistance 34. That did no harm in

his system. It produced no loss because it was not connected in series with resistance 51. In the defendant's apparatus they did not need so much resistance because they already had a system in which the radio frequency potential had been greatly reduced. So that they needed no more than the 50,000 ohms, and in their system it would be a detriment to increase that resistance because that would have lowered the potential available for automatic volume control.

Q. The years 1926 and 1927, around there, you were actively engaged, were you not, in the designing of broadcast radio receiving sets, or have I gotten the years wrong?

A. I perhaps was not as active in the design at that time as I had been a few years before, but I was still active in the radio field, serving on committees of the Institute of Radio Engineers, and also on their Board of Directors, and I was in general touch with radio matters in that period.

Q. I think you retired from that activity some time later, didn't you, Professor?

A. I think it was about the end of 1928, if I remember correctly.

Q. Having regard to that period when you were still active and kept in touch with the facts, will you tell us what effect the advent of the screen grid tubes had on the amplification as to the possibility of getting amplification in these tuned radio frequency sets?

A. The screen grid tubes were better amplifiers than the previous triode tubes, but the difference was not of a different order of magnitude. That is the difference was not very great. There was quite a difference in the way in which the tube had to be used. The screen grid tube had a very high resistance internally in its output circuit. It also had a correspondingly high

amplification factor, because those two things are intimately associated with one another. In fact, the ratio of one to the other is the mutual conductance of the tube which has been referred to, and that was not very different in the screen grid tube from what it was in the preceding triodes. That is, contemporary tubes of the two designs had about the same mutual conductance.

Now, in the old tubes, the triode tubes, which had a low amplification factor, had a correspondingly low plate resistance and it was then possible and usual to use with those tubes an output transformer having a high step-up ratio. That step-up ratio was usually more than 10 to 1. The amplification obtainable from a one-stage of amplification was, therefore, obtained mainly in the transformer rather than in the tube itself, although of course it could not be obtained from the transformer unless the tube had a suitably high mutual conductance. The screen grid tube, on the other hand, could not advantageously be used with the step-up transformer. It is commonly used with a one-to-one transformer, or some other form of coupling, not stepping up the voltage. The major effect, therefore, in changing from the old triode to the screen grid tube was to change the place in which the amplification was produced, rather than to make any large change in the amplification itself.

Q. Well, it has been brought out here that the Wheeler system required a higher amplification of the signal before it was sent to the detector than the old system?

A. Yes.

Q. Would you say whether or not in your knowledge and experience such higher amplification was available for the manufacture of radio receiving sets in 1926?

A. I consider that it was available.

Q. Will you give attention to the testimony of Mr.

Friis that has been stipulated into this case with respect to the receiving set that he built and referred to as Friis Exhibit 9-B. You probably don't know the exhibit number, but have you familiarized yourself with that testimony of Mr. Friis?

A. I have read that testimony and I was present when he gave the testimony.

Q. Do you know whether or not in that receiving set there was enough amplification developed before the detector to have served for Wheeler's purpose?

A. Yes, there was. As I remember it, he testified that he had 16 volts available for automatic volume control, which is greater than the 10 volts which Wheeler contemplated in his early work, that is, in his Washington receiver.

Q. Something has been said here, Professor, of the use of the diode detector or what is called Fleming valve as a radio receiving detector in the early days of radio reception; are you acquainted with that?

A. I am acquainted by the literature. The Fleming valve had passed out of the art before I entered it in 1915.

Q. It had been superseded by what?

A. It had been superseded by the triode detector.

Q. From your reading of the art, can you tell us about the use of the Fleming valve as a detector and particularly about the amount of resistance in the output circuit, and whether that was sufficient to give it a linear characteristic?

A. Yes. The Fleming valve had a relatively high resistance as compared with the modern diode, and was used to feed ordinarily a telephone receiver whose resistance was very low. The resistance of the telephone receiver was certainly only a small fraction of that of the Fleming valve, and even if we should compare the

impedance of the telephone receiver, which I think would not be entirely legitimate for this process, but even if we should make that comparison, its impedance would not be of a higher magnitude than the Fleming valve, and probably would usually be less. It was customary, in fact, in discussing the action of the Fleming valve, as well as other detectors at that time, to neglect the impedance of the telephone; to consider the diode itself as making up practically the whole circuit. Under those conditions, the detecting action was always predominantly dependant on the characteristics of the tube. The tube was not itself a linear tube any more than a diode is today and, therefore, it was not possible to get linear detection, and no one, insofar as I know, even considered such a possibility.

Q. Professor, I am going to read Claim 1 of the Wheeler patent and ask you to follow the circuit diagram of defendant's set 2-B and identify the elements as I go along. The first thing in claim one is: "In a signal receiver having a carrier-frequency amplifier", can you identify that in defendant's set?

A. The set, the whole set, is a radio receiver and the carrier frequency amplifier consists of the vacuum tubes 6-A-7 and 6-D-6 with their associated coils and condensers, and of course the resistance and power sources.

Q. Now, the next element in the claim is: "which includes at least one vacuum tube having a cathode and a control electrode" do these amplifier tubes 6-A-7 and 6-D-6 have that?

A. They both do; yes, sir.

Q. The next element is: "a two-electrode rectifier coupled to the output circuit of said amplifier"; identify that, please.

A. That is the diode section of the tube 33, or 75; the diode section having the anode 35-12 and the cathode 38.

Q. And that is coupled to the output circuit of the amplifier through what?

A. Through the condenser 2. The tuned circuit made up of the coil 31 and its condenser may properly be considered as part of the amplifier.

Q. The other element is: "a high resistance connected between the rectifier anode and the amplifier cathode"; do you find such a high resistance so connected?

A. Yes. The resistance 51 is so connected.

Q. The next element is: "means including said resistance for maintaining the average potential of said anode normally negative relative to at least part of said amplifier cathode and increasingly negative with increasing amplified signal output from said amplifier"; do you identify that in defendant's system?

A. Yes. The resistance 51 has that action and it is connected from the point 52 through the resistance 53 and the lead 36 back to the grid 11 of tube 9 and also the grid of the 6 tube.

Q. And how is the anode of the tube, of the rectifier tube maintained normally negative and increasingly negative as the signal increases?

A. It is maintained negative in the normal operation of the receiver by the fact that the electron stream goes from the cathode 38 to the anode 35, and thence flows as a negative direct current through the coil 31, through the resistance 34, and then through the resistance 51 to ground, which means back to the cathode.

That negative current in flowing through resistance 51 builds up the negative potential which exists at its terminal 52. That condition is even present in the absence of a signal because of the initial velocity that the electrons have in issuing from the cathode. That is, they are evaporated out of the cathode with a certain

velocity and some of them will then go over to the anode. That is a relatively unimportant fact that need hardly be mentioned.

When the signal is increased in strength above whatever its original value may have been, the flow of electrons will be increased, and that will cause an increase in the current through the path which I have traced, and an increase in the potential built up at the terminal 52 of resistance 51.

Q. Now, I think you already referred to the next, the final element of the claim, that is: "and a direct-current connection from said anode back to said amplifier control electrode whereby the amplification of said amplifier is regulated automatically", have you not?

A. Yes, I referred to that in general in indicating the operation of resistance 51. That direct current connection traced out in detail begins at the anode 35, goes through the coil 31, and then down through the resistance 34, then to the left through resistance 53 and lead 36 and then through the coil 7, associated with the antenna, and then through the switch to the grid 11. It also goes through connections not accentuated to the grid of tube 6-D-6.

Q. Now, is it possible when a triode detector is used for this a.v.c. purpose to have this negative potential on the anode in the way described in this claim?

A. No, the anode of a triode always has to be positive relative to its cathode, and this claim calls for the negative potential which is therefore not consistent.

Q. In some of the claims of the patent, Professor, the electrodes which are marked 35 and 12 in the Wheeler patent, and so marked by you in the defendant's system diagram, that is the plate and grid connected together to form a single electrode, is referred to in some of the claims as the anode of the diode and in other claims as

the output electrode of the diode. Do you attach any significance to that or do they mean the same thing?

A. I think they mean the same thing. As I understand it in reading the claims, the term "output electrode" is used for convenience of reference subsequently in the claim, and I think it is a perfectly appropriate term to use in place of "anode" in this connection.

Q. Now, I will ask you to turn to claim 10, without going over the whole of it, and consider just that which is added to claim 1 and compare that with the defendant's system. The thing that is added is expressed in claim 10 as follows: "A condenser connected between said amplifier cathode and a point on said direct-current connection, and resistance in said direct-current connection between said point and said anode which with said condenser provides a time constant predetermined to filter out voltage fluctuations at frequencies of signal modulation." Do you find that in the defendant's system?

A. Yes; the condenser in question is 54 on Exhibits 2-B and 3-B, at the left center of the diagram. The resistance is marked on each exhibit as 53, and the values of the resistance are in each case one megohm, and the value of the condenser on Exhibit 2-B is one-tenth micro farad. The value on Exhibit 3-B is not very clear in my copy here. I think it is the same. Those values are entirely suitable for giving a time constant such as described in the claim, and to filter out the voltage fluctuations at the frequencies of signal modulation, as referred to in the claim. The values, as a matter of fact, are not very critical.

Q. Your discussion of this Exhibit 2-B, which we have just been over, comparing it with these claims, will apply or will it apply, to Exhibit 3-B also?

A. Yes. I think in most cases I included that in my answer, but if I did not I intended to in each case.

Q. Now, will you look at Exhibit 2-B, and tell us whether or not the tuning meter is coupled to the output circuit of the amplifier?

A. Yes, it is. The output circuit of the amplifier may very well be considered as between the two terminals of coil 31, although it really makes no difference just where we consider it, so far as this coupling is concerned. If we then start at the high potential terminal, which is the upper terminal of coil 31, we have a path through the coil 31, through resistance 34, thence to the left through resistance 53 to a junction point, and then down to the grid of the visual indicator, which is the tube 6-G-5. That constitutes a coupling from the output of the amplifier to the visual indicator.

The Court: Mr. Davis, where is the place in the claims that reference is made to this visual indicator?

Mr. Davis: It is claim 13. Wait a minute. It is claims 6 and 7; I was wrong about that. Claims 6 and 7, the words, "and a visual indicator coupled to the output circuit of the amplifier and responsive to the relative magnitude of said output, whereby the visual indication follows the strength of the detected signal and thereby facilitates tuning."

Q. (By Mr. Davis): Now, Professor, I am going to ask you whether or not as a result of this coupling which you have just traced, the arrangement in defendant's system is such that the Magic Eye is responsive to the relative magnitude of the output of the transformer?

A. Yes, that is correct.

Q. And does thereby the visual indication follow the strength of the detected signal and facilitate tuning?

A. Yes, it does. Your previous question referred to the output of the transformer and the claims referred to the output of the amplifier.

Q. It should read, "amplifier". You understood me to mean that?

A. The answer was correct either way.

Q. Yesterday you compared the defendant's circuit of 175, that is 2-B, with the Evans patent, and pointed out the differences between them. Will you say whether or not that same discussion would apply equally well to the 178 defendant's receiver?

A. Yes, I had in mind including the 178. I think I neglected to say so.

Q. As I understand it, Professor, Mr. Wheeler, was at the time he made his invention associated with the same company that you were then associated with?

A. Yes.

Q. The Hazeltine Company?

A. Yes.

Q. By the way, are you any longer associated with that company?

A. No, I am not.

Q. And he disclosed, I understand, this automatic volume control system which is shown in his patent to you at some time; about when, do you remember?

A. We had, I think, some earlier conversations, but the only one that I can clearly recollect, occurred, I think not very long before the presentation of his paper before the Institute of Radio Engineers.

Q. That is the paper that was presented in January, 1928, that is shown from this—

A. (Interrupting): I think that is the publication date, isn't it? I think the paper was presented in the fall of 1927.

Mr. Adams: November 22, 1927.

Q. (By Mr. Davis): November 22, 1927, that is right; that is your recollection?

A. Yes.

Q. Now, when Mr. Wheeler disclosed this at that time, you were familiar, were you, with the broadcast radio receivers and radio frequency amplifiers then in existence?

A. Yes, I had given a great deal of study and attention to them.

Q. Will you tell us whether or not this disclosure of Wheeler's seemed to you an obvious application?

A. Quite the contrary. It came as a distinct shock to me that Wheeler wanted to use a diode. I had the immediate feeling that he was taking a step backward because the diode was generally understood to be something that had been superseded as a radio detector. I was also struck by the way in which he intended to use it. He explained to me that he intended to use it with a high external resistance so that the greater part of the rectified voltage would appear across the resistance and the diode itself would play only a relatively minor part while the current was flowing. That is, the diode characteristics would have very little to do with the intensity of the potential developed, and the resistance outside would almost completely determine it. That was quite a new idea to me at the time. He also explained to me that to get such operation it was necessary to use a relatively high signal level, and that was a suggestion and a use that I had not previously encountered.

Q. You have read and discussed here this patent to Evans, 1869323 and the other Evans patent of which it is a division, 1738652. Now, will you say whether or not either or both of those patents instructs or suggests the use of a diode.

A. No, quite the contrary. The only thing which is shown as a detector is a triode, and there are quite a number of references to the grid of this triode, and also to the plate of the triode which would not be intelligible if a diode was contemplated by the patentee.

Q. I may have asked you this before, but I will make sure and ask you again; does the Heising patent 1687245 disclose an automatic volume control system?

A. No, not at all.

Mr. Davis: It is stipulated at this point, with agreement of Mr. Darby, that the definition of automatic volume control of the Standards Committee of the Institute of Radio Engineers, as it appears in this document I have in my hand, which is the 1938 Standards booklet, is as follows: "Automatic volume control: An automatic volume control is a device which automatically reduces the total amplification of the signal in a radio receiver with increasing strength of the received signal carrier wave."

That is all.

The Court: I think before you start, Mr. Darby, this may be in the record, Mr. Davis, but it came to me; when did you sever your connection with the Hazeltine Corporation?

A. I think it was at the end of 1928. Approximately that time. Then, about 1934 I bcame connected as a consultant for two years, and subsequent to that I have had no connection with the corporation.

The Court: Do you have any interest in the outcome of this case, other than appearing here as an expert witness?

A. No, your Honor.

The Court: That is all.

Mr. Davis; Mr Adams has some notes he wants me to look at, but I will be looking at them while the cross examination goes on and then impose on Mr. Darby's good nature, if I may, and your Honor, in case I want to ask another question.

The Court: All right.

Cross Examination

By Mr. Darby:

Q. It is, of course, your name that is included as part of the name of the corporation?

A. Yes.

Q. And you took part in forming that corporation?

A. Yes.

Q. And you had a substantial financial or stock interest in the corporation when it was formed?

A. Yes.

Q. Do you still hold any of that interest or any part of it, in the corporation?

A. No.

Q. You disposed of that all?

A. I disposed of that.

Q. Will you please look at Figure 1 of the Wheeler re-issue patent in suit, and very briefly what is the output circuit of the diode rectifier?

A. The output circuit of the diode rectifier is the resistance 51, the resistance 34, the condenser 37 and then the connection for automatic volume control proper beginning at resistance 63 and going back and including the condenser 54 and the coil 7 to the grid 11.

Q. In other words, the output circuit of the diode rectifier is coupled to the input circuit of the amplifier, is that right?

A. Yes.

Q. The output circuit of the rectifier isn't coupled to the output circuit of the amplifier, is it?

A. Yes, I think it is, because the diode having only two terminals, its input and output terminals are really

identical and so its output terminals are coupled to the output of the amplifier through the condenser 2 and, of course, through the common connection represented by the horizontal line running across the diagram.

Q. In other words, as I understand you, there is a direct coupling between the output circuit of the rectifier to the input circuit of the amplifier but an indirect or intermediate coupling between the output circuit of the rectifier and the output circuit of the amplifier, is that right? That is, there is something interposed between them?

A. There is a condenser interposed in the one case. In the other case it might be proper to consider the connection as going all the way back to the grid without any interposition. But, of course, there is actually in that circuit a radio frequency coil 7 which has other functions, essential functions, in the radio frequency system which is independent of its carrying potential for automatic volume control.

Q. And, as a matter of fact, there is interposed between the vacuum tube amplifier 9 additional vacuum tube amplifiers 15 and 23; that is, between the first radio frequency amplifier and the rectifier, is that right?

A. Yes. You are referring to the tubes as the amplifier.

Q. Yes.

A. The complete amplifier includes the coils and condensers also.

Q. Surely. Now, it is the terminology in those days that I understand you were familiar with the literature pertaining to the Fleming valve, the terminology in those days was to refer to both the three-electrode device and the two-electrode device as vacuum tube devices, wasn't it?

A. The vacuum tube was the common American term. The word "valve" was commonly used in England, and

the Fleming valve having been developed there was often called a valve.

Q. And it likewise was customary to refer to them both as thermionic devices, wasn't it?

A. Oh, yes, they are both thermionic.

Q. And the patent in suit makes this statement on page 2, beginning line 18: "The rectifier employed is a two-electrode rectifier which may be of the type commonly known in the art as a 'Fleming' valve, or may consist of an equivalent, such as a three-electrode vacuum tube, as shown, having its grid 12 and its plate or anode 35 directly connected together to comprise in effect a single anode." Now, having in mind that this application was filed in July, 1927, that the original application was filed in July, 1927, were you still actively engaged in designing radio receiving sets at that time?

A. I don't think I was actually engaged in the designing at that time, but I was still interested in the design.

Q. That is, you had not, as you stated, retired from that activity at that time?

A. That is correct.

Q. Now, referring to Figure 1 of the Wheeler patent, do you agree with Mr. Kelley that none of the direct current that goes through the resistance 51 goes through the resistance 34 in Wheeler?

A. Yes.

Q. You agree with that. And, do you agree with Mr. Kelley with reference to defendant's receivers, Models 175 and 178, that all of the direct current that goes through resistance 51 or the resistance you have marked 51 on the diagrams, Exhibits 2-B and 3-B, goes through the resistance 34?

A. Yes.

Q. You agree with that?

A. Yes.

Q. Now, in that respect at least the disclosure of Figure 1 of the Wheeler patent and the defendant's receivers, are different, is that right?

A. Yes.

Q. And that difference is due to the fact that there is that difference in the circuits, is that right?

A. Yes.

Q. And I think you also agreed with Mr. Kelley, or will you agree with Mr. Kelley if you haven't, that the defendant's circuits as shown in Exhibits 2-B and 3-B do not employ the rejector circuit consisting of the resistance 34 and condenser 37?

A. They do not employ the resistance 34 and the condenser 37 as in Figure 1 of the Wheeler patent.

Q. Let me put it this way; while defendant's receivers avoid passing on the alternating current component to the first audio-frequency amplifier, they do not employ a resistance 34 and a condenser 37 for that purpose, is that right?

A. No, that is not quite right.

Q. Will you state it correctly for me?

A. By alternating current I understand you to mean high frequency current.

Q. High frequency, yes?

A. They largely avoid it by the way in which they use the condenser 2.

Q. Yes.

A. They don't completely avoid it, and to supplementally get rid of that high frequency alternating current they use a resistance and a natural capacitance which takes the place of the condenser, and that is resistance, which is marked 34, in Plaintiff's Exhibits 2-B and 3-B, and the condenser is a natural capacity which is not shown in the drawing, but which is present physically in the apparatus.

Q. Now, with further reference to the comparison between a three-electrode detector and a two-electrode detector, I think that you pointed out very clearly to the Court that one inherent, that is, one difference which is inherent in the use of a two-electrode device, as distinguished from a three-electrode device, is that the two-electrode device or diode, gets its energy from the signal current, whereas in a three-electrode device or triode, it gets its energy from a battery, is that right?

A. Yes.

Q. In other words, when you use a three-electrode device, you couple in the plate circuit a battery or a current source, to supply what we call the plate voltage?

A. Yes.

Q. But with a two-electrode device you do not use a battery in the plate circuit, is that right?

A. That is usually right, that is right in the diodes we have considered here.

Q. Yes, and that is a characteristic of diode as distinguished from triode, from which follows the fact that the diode gets its energy from the signal current, whereas the triode gets its energy from the battery included in its plate circuit?

A. Yes.

Q. And that of course was well known at the time you first began your work, your active connection in radio work, some time in the early 1920's.

A. Yes.

Q. And if—

A. That date isn't right; I commenced my radio work in 1915.

Q. 1915. I had the 1920's in my mind, because I think you stated the use of the diode as a detector was obsolete at some time in your work, and I did not recall when it was; was that at the very beginning of 1915?

A. I never saw a Fleming valve until very recently. I am not sure whether ship operators were still using them on the English vessels at that time. They were used there long after they were abandoned by amateurs and engineers in this country.

Q. Well, you knew or had heard, had you not, that during the fight between Marconi and DeForest involving the Fleming valve patent on the one side and the DeForest Audion on the other side, that the Marconi Company were using the Fleming valve, or two-electrode device, as a detector in their commercial stations?

A. I do not remember whether they were then using them, or had used them, but they were not used by radio people that I was in contact with at that time.

Q. Did you ever use any of the two-electrode devices in experimental work, in your laboratory, experimental work that you conducted?

A. Not for radio detection, at least of the vacuum tube type. I have used crystal detectors, but not the Fleming valve vacuum for radio receiving sets.

Q. And you agree with me, I think, that the addition of the grid to the vacuum tube, it was the addition of the grid to the vacuum tube, together with the plate current in the output circuit of the three-electrode vacuum tube detector, that enabled the device to serve simultaneously as a detector and an amplifier?

A. Yes.

Q. And that amplification was more effective, or more desirable to have amplification with a negative bias on the grid which was supplied by what you call the "C" or negative bias battery, included in the grid circuit?

A. That was usually true, yes.

Q. And there being no grid in a two-electrode device, there was usually no battery or biasing battery employed in the plate circuit of the two-electrode device when used

as a detector; that is right, isn't it?

A. I think that wasn't quite so common. As I remember it, the earliest use of the Fleming valve was without any battery in its circuit—there was only one circuit, of course, there—but that later on it became more customary to put in a battery to get on the sensitive point of the curve where the tube was the best detector.

Q. My recollection corresponds with yours fully, so that so far as a biasing battery is concerned, that was a matter of option which became more and more prevalent in use with the two-electrode device, when it was used as a detector; is that right?

A. I think so.

Q. So that you as an engineer, if asked to substitute a two-electrode device as a detector for a three-electrode device as a detector in a circuit, would know that in making that substitution you would take out of the circuit the vacuum tube itself with the three electrodes, as well as the plate battery, and substitute for it a two-electrode device without a plate battery, and you might or might not put in the two-electrode device a biasing battery, is that right?

A. Yes, the biasing battery would, of course, be a plate battery because there would be just that one other electrode besides the cathode, and that might be called a plate.

Q. And the use of a biasing battery, I think you agreed with me a minute ago, was more or less optional with the man in the use of a two-electrode device as a detector?

A. Yes. We are talking, as I understand it, about a radio signal detector?

Q. Yes, a radio signal detector. Now, will you turn to the second Evans patent, please.

If you as an engineer I take it from your answers, were asked to substitute a two-electrode device for the three-electrode device 8, the detector in that circuit, you would know that with that substitution there would be eliminated the battery 16 and optionally the battery 17, would you not?

A. Well, of course, there would only be one circuit in which a battery could be placed, and you might call that either 16 or 17. There would not be any distinction. If I were asked to do that in the Evans system, as of these past dates, I believe that my first reaction would be whether it was possible to make the substitution. That is, whether it would be possible to get the effect that Evans is trying to get.

Q. Read my last question.

(Question was read by the reporter.)

A. I would know that there would remain in effect only one battery and that would be optional.

Q. I still think you haven't answered my question, Professor.

Mr. Davis: I think your question is answered. Why don't you ask another one?

Mr. Darby: I am very anxious to get an answer to this one, Mr. Davis.

The Court: Let's hear the question again.

(The question was read by the reporter.)

The Court: Read the answer.

(The answer was read by the reporter.)

Mr. Davis: Do you understand, Professor, what is lacking in the answer? Do you know what Mr. Darby now wants to get out of you?

Mr. Darby: Yes or no, I would like to get yes or no, if it is possible.

The Court: I think you have. Of course, I think his other answer, I think, Professor, the answer that I was

looking for was one of three, yes, no, or I don't know. I think the reason you got that answer, Mr. Darby, was because the witness was trying to be helpful.

Mr. Darby: I do not question that in the least.

The Court: That is, in other words, part of your question that is difficult for me is what you mean by 17 being optional. The witness' answer is that it would be optional to remove either battery; isn't that the way you meant to answer?

Mr. Darby: That is the reason—

The Court: Mr. Hazeltine.

A. Not exactly, your Honor. There could in effect be only one battery after you made this into a diode, because there would be only one circuit, so the question did not entirely to my mind make sense. I can answer—

The Court: I do not know that I am helping any here. I think he can answer it as well as I could under the circumstances, that is not the difficulty with the knowledge, it is the difficulty in understanding the question.

Mr. Darby: I think maybe I can clear it up. I do not believe there is any real disagreement between us.

Q. (By Mr. Darby): You would know, would you not, that the battery 16 would be eliminated and—

The Court: Wait, stop there.

Mr. Darby: All right.

A. No.

Q. (By Mr. Darby): You wouldn't. That is what I was afraid of stopping there for, your Honor. You know that the battery 16 would be eliminated and that the battery 17 might or might not be eliminated?

A. No.

Q. You wouldn't know that. All right, I am content to let it rest right there, unless you desire to make some explanation.

A. No.

Q. You have no desire. Thank you. I don't know, I think I will listen to an explanation. Will you reconcile that answer, Professor Hazeltine, with the answer you gave just a few minutes ago which was re-read to the Court?

A. The battery 17 is in a direction to make the grid negative. The battery 16 is in a direction to make the plate positive. If this were to be changed over to a Fleming valve there would be only a single electrode in place of both the plate and the grid and if an optional battery were used with that it would be in the direction to make that electrode positive rather than negative, so that it would be the battery 17 that would be eliminated, and the battery 16 would be optional.

Q. Well, do you wish to change your prior testimony now that the elimination, I mean the utilization of a two-electrode device as a rectifier eliminates the use of a "B" battery current?

A. I do not think that I said that. I think I brought out the fact that the bias itself would be equivalent to a "B" battery. You did not ask me as to the polarity of that bias, so the question as to whether it was positive or negative did not come up, but the fact is it would be positive, which would be the same as the "B" battery polarity.

Q. Did you or did you not agree with me that a characteristic and inherent difference between a two-electrode device as a rectifier or detector and a three-electrode device as a detector, is that the two-electrode device does not use a B battery source of current?

A. No.

Q. Whereas a three-electrode device does?

A. I don't think I said that. If I did, I should not have said so. And, I would say substitute the word "need" for "use". It does not need a direct current source, but it may use one.

Q. Maybe you would like to change the testimony that customarily a B battery was not used with a two-electrode detector? Do you want to change your testimony?

A. I don't think that was my testimony; no, sir.

Q. That was not your testimony?

A. I think it was my testimony, and I thought you agreed with me, that it was the usual practice to use a battery with a Fleming valve.

Q. Let me ask you this; if you use a battery with a Fleming valve—withdraw that—you understand when I say B battery for the Fleming valve, that I intend to mean the plate battery, or did you? Were you drawing a distinction between a B battery and a plate battery?

A. No, sir.

Q. Let me ask you this, then, when a plate battery is employed with a Fleming valve, does the device obtain its energy from the signal or from the plate battery?

A. It certainly would obtain some of it from the signal, and I would expect that that would be the predominant effect. I think it might very well obtain some of it also from the battery.

Q. So that when a plate battery is employed, a plate voltage is employed, with a two-electrode device, then the distinction that you drew between the use of a two-electrode detegtor and a three-electrode detector, at least, one of the distinctions that you drew, namely, that the two-electrode device obtains its energy from the signal, whereas the three-electrode device obtains its energy from a B battery no longer exists; would you agree with that?

A. Not fully. As I said in my last answer, I thought even if a battery were used with the two-electrode device, still the main part of the energy would come from the signal.

Q. Would it come from the signal any more in a

two-electrode device, than it would in a three-electrode device?

A. Yes.

Q. Why.

A. Well, that can be illustrated by cutting off the battery. If you cut off the battery in the two-electrode device you would still get a response; perhaps almost as good as before. If you cut off the battery in the three-electrode device you get no response whatever. The system is dead.

Q. You say you get a response almost as good as it was before, then what useful purpose would the B or plate battery serve in a two-electrode device?

A. It serves as a bias to get on the best operating point of the characteristic curve.

Q. Then it would no longer be serving as a plate battery in the same sense that a plate battery is employed in a three-electrode device, would it?

A. I am only willing to call it a plate battery because you did. I wouldn't call it a plate battery because there is only one circuit besides the heating circuit. You can put a battery in to heat the filament of the two-electrode device and then put in one other battery besides that. If you like, it may be called a plate battery. It would go to the plate.

Q. What would you call it, a bias battery?

A. I think I would prefer biasing battery; yes, sir.

Q. In other words, its function to establish a bias is its principal and intended function in the circuit?

A. Yes, sir.

Q. You think that is its sole function in the circuit?

A. I think that is the only important function.

Q. And, now, we are back to where we were a few moments ago. I think you agreed with me when a bias

battery was employed with the two-electrode device, when used as a detector, it was optional?

A. Yes.

Q. All right. I only want to direct your attention to one of the patents of the prior art offered by Mr. Davis, and that is the Falknor patent. That is these are these additional patents that Mr. Davis referred to. As I understand your testimony, it is that you understood that this patent is directed to automatic volume control; is that right?

A. Yes.

Q. And the object that he states on page 1, line 4, namely, "One object of my invention is to provide means whereby a radio signal can be received and maintained at a substantially constant volume", is the same objective as that contained in the Wheeler patent, is that right?

A. Yes.

Q. And, would you say that the description beginning at line 15 of that patent, and running throughout that paragraph, is a fair and accurate description of the necessities for automatic volume control?

A. The description of one of the necessities.

Q. And that one necessity is, likewise, set forth in the Wheeler patent?

A. Yes.

Q. Now, I note for example, referring to the claims of this patent that, take claim 4 for example, he recites:

> "In a signal-receiving system, means including a thermionic tube for deriving an indication from an incoming signal".

What he refers to there is the effect of the incoming signal on the amplifier, is that right?

A. I would suppose that the indication was the indication of a telephone receiver. I would think that would apply to the upper half of his figure.

Q. All right, you think it is the indication that he would receive in the telephone receiver?

A. Yes.

Q. So that when the claim continues:

> "—thermionic tube for deriving an indication from an incoming signal, separate means including a thermionic tube for deriving a potential proportional to the amplitude of said signal",

He is referring there to the use of a rectifier or detector; would you agree to that?

A. Yes.

Q. And then the next element is:

> "and means whereby the gain in said first thermionic tube is controlled by said derived potential",

that is the automatic volume control connection, is that right?

A. Yes.

Q. Now, with your understanding of the invention as claimed by Falknor, I ask you to have in front of you the defendant's circuit, and ask you if that claim of Falknor correctly describes the defendant's receiver?

A. No, sir.

Q. In the defendant's receiver, is it a signal receiving system?

A. Yes, sir.

Q. Is there means including a thermionic tube for deriving an indication from an incoming signal?

A. Yes, sir.

Q. Is there separate means including a thermionic tube for deriving a potential proportional to the amplitude of said signal?

A. No, sir.

Q. There is not. So, is there means whereby the

gain in said first thermionic tube is controlled by said derived potential?

A. Not precisely, because the said derived potential isn't present, as I explained before. Otherwise, that would be correct.

Q. I see. Now let us apply the same thing to claim 5. Is there in defendant's receivers and each of them, a signal receiving system?

A. Yes.

Q. Means including a thermionic tube for deriving an indication from an incoming signal?

A. Yes.

Q. Separate means including a thermionic tube for deriving a potential that—I think you will agree with me the word "various" is a typographical error and should be "varies"?

A. Yes.

Q. (Continuing): —that varies with the amplitude of said signal?

A. That is not present.

Q. And the last element is, means whereby the potential applied to the grid of said first thermionic tube are controlled by said derived potential; I presume that being the same as the last element of the preceding claim your answer would be the same?

A. That is right.

Q. In both of those claims, the means of Falknor for deriving a potential that varies with the amplitude of the signal is the detector tube and resistance, is it not?

A. Will you read that, please?

(Question read.)

A. There are two detector tubes in the Falknor patent, and the one that is here referred to seems to be the second one, number 22.

Q. And that is the means separate from the amplifier

which serves the function of deriving a potential through the resistance, is that right?

A. Yes.

Q. In your direct examination, Professor, you referred to, or at least drew a distinction between automatic volume control or automatic amplification control secured by a diode or two-electrode device on one hand, and by a three-electrode device on the other hand. Have you a copy of the original Wheeler patent of which the patent in suit is a re-issue?

A. Yes.

Q. Will you refer to the drawings of that original patent, taking them in order; Figure 1 of the original patent showed the diode type of automatic amplification control, did it not?

A. Yes.

Q. Figure 3, which is the next wiring diagram, again shows the diode type of automatic volume control, is that right?

A. Yes.

Q. Figure 4 shows the triode type of automatic volume control does it not?

A. Yes.

Q. And let me ask you in connection with Figure 4 what is the potential of the output or plate electrode of the triode detector in this figure; is it positive or negative?

A. Positive.

Q. It is positive by reason of the battery marked 100?

A. Yes.

Q. That is connected in the plate circuit?

A. Yes.

Q. Now, Figure 4—check me on this, will you, please —on page 1 of the original patent, line 95, it is described in this language:

"Figure 4 represents the present invention embodied in a radio receiver including a two-stage radio frequency amplifier, a detector, and a two-stage audio-frequency amplifier";

is that right?

A. Yes.

Q. The next wiring diagram is Figure 5, which I see by its brief description is intended to show a modified form of coupling arrangement, and is there shown in Figure 5 the detector?

A. Yes, sir.

Q. Is it a triode or diode type?

A. Triode.

Q. And what would be the potential on the plate electrode or output electrode?

A. It would be positive.

Q. And Figure 6, is that a diode or triode?

A. That is a triode.

Q. And that is described on page 2 of the specification of the patent as follows:

"Figure 6 shows a diagrammatic arrangement of a radio receiver incorporating the present invention, and operated entirely from a rectified and filtered alternating source of current, thus eliminating the 'A', 'B' and 'C' batteries now so widely used";

that is correct?

A. Yes, sir.

Q. And Figure 7 shows a diode type of connection, is that right?

A. Yes.

Q. And I think you testified on direct examination with reference to page 86 of the Wheeler notes, of his notebook. Will you please refer to the wiring diagram and automatic volume control arrangement shown on

that page, and tell me which of the wiring diagrams of the original patent, which showed the three-electrode a.v.c. arrangement that is the same or substantially the same as the diagram on page 86 of the Wheeler note-book?

A. It may take me a moment, because I have not previously made such a comparison.

Mr. Davis: We are willing to agree that it is nearer to Figure 4, it is approximately the same.

Mr. Darby: Substantially the same in Figure 4.

Mr. Davis: Yes.

Mr. Darby: All right, I will accept that. It is substantially the same in Figure 4, and I think you will likewise agree at the same time, won't you, that Figure 4 of the original Wheeler patent was separately patented through a divisional application which patent is number 1879862, granted September 27, 1932, on a divisional application that was filed November 10, 1930.

Mr. Davis: Well, I think the way you phrase it may be misleading. I am willing to agree that the circuit of Figure 4 of the original Wheeler patent was the circuit illustrated and described in the patent 1879862, and that certain features of that disclosure were patented in that patent.

Mr. Darby: That is sufficient.

The Court: Supposing you come back at two o'clock.

Mr. Darby: I think that would save a lot of time, because I can boil this down materially.

The Court: All right.

(Thereupon, a recess was taken until 2 o'clock p.m.)

Detroit, Michigan
Thursday, November 2, 1939,
2 o'clock P.M.

Court met pursuant to recess.

LOUIS ALAN HAZELTINE, was thereupon recalled as a witness, being previously sworn, testified as follows:

Cross Examination

By Mr. Darby:

Q. Professor Hazeltine, turning, if you please, to the second Evans patent, I understood you to testify that with the arrangement shown in the drawing of the Evans patent for that arrangement to operate on the linear characteristic of the detector, as distinguished from the square law, three changes would be needed, as follows: First, a higher value of resistance; second, more voltage in the B battery 16, and, third, more voltage in the C battery 17; is that correct?

A. Yes, sir.

Q. Then, in order for that system to operate on a linear characteristic of the detector, you wouldn't have to change the circuit, you would merely change the value of those three instrumentalities, is that right?

A. You would have, in addition, to supply a sufficiently strong signal, and that might make it necessary to introduce more amplification?

Q. But, if we assume that the signal coming into the primary coil of the transformer 10 was strong enough, then in order for the Evans arrangement shown in the drawing to operate on the linear characteristic of the

detector as distinguished from the square law characteristic, you would not have to change the circuit; all you would have to do was change the value of those three instrumentalities, namely, the two batteries and the one resistance, is that correct?

A. That is correct, except that you picked out the wrong transformer for the input. The input is at the other end.

Q. I am sorry, I should have said the primary 1 of the transformer 6.

A. Yes.

Q. And with that change my statement is correct?

A. Yes.

Q. Now, what value does Evans give in his patent for the battery 17?

A. I do not remember that it is stated in the patent.

Q. That is my understanding, too, Professor; and it is likewise my understanding that no value is given in the patent for the battery 16; is that correct?

A. I believe that is correct.

Q. And, likewise, there is no value given for the resistance 19, is there?

A. I believe not.

Q. Now, would you refer to the Slepian patent just for a moment. In the arrangement shown in Figure 1 of Slepian there is employed a three-electrode detector amplifier, is there not, namely, the tube 1?

A. Yes. That tube 1 might be called very broadly an amplifier, although it is not an amplifier in the general sense in which we have been using that term in this case.

Q. Does the action of the diode tube 18 alter or regulate the negative bias on the grid of the amplifier?

A. It regulates the negative potential on the grid of the amplifier. That negative potential is not most

usually called a bias. The word "bias" is usually used to mean a potential which remains fixed during the reception of the signal.

Q. Slepian calls it a bias, doesn't he? I direct your attention to column 2 of the first page beginning of line 109?

A. Yes, I find that he does, but my statement is correct that that is not generally called a bias, and I think not very accurately called a bias.

Q. Well, whether it is called a bias or what it is called, the device is used for increasing the negative charge on the grid condenser 8, is that right?

A. For intermittently increasing it?

Q. Yes.

A. Not continuously.

Q. Yes. Now, does the Slepian arrangement accomplish that automatically?

A. Yes.

Q. Will you turn to Heising patent. Is the function of the two-electrode device in Heising to regulate the amplification of the three-electrode amplifier?

A. Yes, as a stepping stone to achieving the purposes of the invention.

Q. And does the two-electrode device in Heising accomplish that automatically?

A. Yes.

Q. Now, will you turn to the Espenschied patent, which is in that group of patents which Mr. Davis called to your attention and I think that you already pointed out to the Court that in Figure 3 of that patent there is employed a two-electrode rectifier?

A. Yes.

Q. That is the device R in Figure 3?

A. Yes.

Q. And that illustrates one use of a two-electrode

rectifier where a plate battery is not employed, doesn't it?

A. That is correct.

Q. And it also illustrates one use of that device where a biasing battery is not employed with the two-electrode device?

A. That is correct.

Q. Have you in mind that this patent—I think Mr. Davis pointed out this is a patent that issued prior to the invention of the Wheeler device—will you please refer to the claims of this Espenschied patent; take claim 7 for example, and I will read it to you and ask you if that correctly describes the defendant's receivers, both of them:

> "In a radio receiving circuit comprising a detector and an amplifier, means associated therewith responsive to the intensity of the incoming signal for changing the gain of the amplifier".

Does that correctly describe the defendant's apparatus?

A. Yes.

Q. Take claim 9:

> "In a radio receiving circuit comprising a detector and an amplifier, means associated therewith responsive to the detector for changing the gain of the amplifier",

does that correctly describe both of defendant's sets?

A. Yes.

Q. And, take claim 10:

> "In a radio receiving circuit comprising a detector and an amplifier, means associated therewith responsive to the changes in the direct current component of the detector for changing the gain of the amplifier",

does that correctly describe the defendant's apparatus?

A. Yes.

Mr. Darby: That is all.

Mr. Davis: I find in one of these notes of Mr. Adams, it calls for a question which really is not redirect.

Mr. Darby: No objection.

Re-Direct Examination

By Mr. Davis:

Q. Professor, Mr. Kelley testified at page 232 in the transcript that in order to obtain linear rectification we, first of all, must have relatively large signal voltages applied to the detecting device. You agree with that?

A. Yes.

Q. And that is true whether it is a diode detector or a triode detector?

A. Yes.

Q. Then he went on to say this, he said

> "Those relatively large signals, however, are much larger for the two-electrode type of rectifier than they are for the three-electrode type of rectifier for the reasons I have already stated. The three-electrode type of rectifier also amplifies at the same time it rectifies."

Do you agree with that?

A. No, sir. The explanation that is given seems to have no connection with the thing that it is intended to explain. The original discussion had to do with the linearity and the fact that further amplification may be required has nothing directly to do with that; and the fact is to the contrary, that for linearity it does not require as high a signal voltage to operate the two-electrode detector as it does the three-electrode detector. The two-electrode detector inherently has a lower resistance and for that reason it can be operated also, if

necessary, with a lower external resistance, and with a lower signal level than the three-electrode detector, or triode.

Q. Then, as to this amplifying idea that Mr. Kelley introduced, as I understand it, it is the potential impressed upon the input circuit of the detector that must be high?

A. That is correct.

Q. In either case?

A. That is correct.

Q. And the fact that the triode produces an amplified potential on the output side has nothing to do with that other problem, is that right?

A. That is right.

Mr. Davis: That is all.

Mr. Darby: Mr. Davis, would this be a convenient time for you to enable me to clean up with Mr. Wheeler?

Mr. Adams: Let me state what those things are you asked me to find out.

Mr. Darby: Your Honor will recall that Mr. Wheeler was to obtain some information for me, and that information has been obtained, and it is this; that so far as the Bosch Company was concerned, it first came on the market with a triode type of automatic volume control in 1930, and then with a diode type of automatic volume control in 1931. Bosch, at the time it came out with these receivers was not licensed by—

Mr. Adams: (Interrupting): Not licensed until January, 1935.

Mr. Darby: Amrad, was licensed since 1923. It never made receivers with automatic volume control. Grigsby-Grunow was licensed. The first time it brought out automatic volume control, which was a triode automatic volume control, and that was followed in 1931 by a diode volume control. Brunswick, Balke, Callander Company,

the Brunswick radio receiver, there is a rather complicated situation because of ownership by Warner Brothers Pictures and Brunswick, Balke, Callender Company, but the fact, so far as we are concerned with them, is that the first Brunswick receiver on the market was the triode automatic volume control in 1930, and no diode was put on the market, although they first built a diode in 1931, but they were licensed under the Wheeler patents.

Mr. Adams: Their manufacturing subsidiary was licensed by the Hazeltine Corporation in 1929. I may say that the reason they did not put the diode on the market appears from the stipulated testimony, and that was that they went out of the radio business.

Mr. Darby: And Stromberg-Carlson, the first receiver incorporating automatic volume control was the triode type brought out in 1929, and the diode type was not brought out until 1931. Both types were manufactured under license of the Hazeltine Corporation. The Crosley—

Mr. Adams: (Interrupting): I do not know what the implication of that is. They were licensed in 1929.

Mr. Darby: They were licensed in 1929 when they brought out their first automatic volume control, and it was a triode.

Mr. Adams: They were licensed prior to that date.

Mr. Darby: Yes, that is what I said. I did not imply anything.

Mr. Adams: All right.

Mr. Darby: The next one is the Crosley, which was licensed under Hazeltine when it first brought out automatic volume control which was in 1930, and consisted of the triode type and a diode type in 1931.

Mr. Adams: Both of that, appears, your Honor, from the stipulated testimony.

Mr. Darby: I also wanted to ask Mr. Wheeler—

Mr. Davis: (Interrupting): I am going to put Wheeler on in a minute.

Mr. Darby: You are going to put him on anyhow?
Mr. Davis: Yes.
Mr. Darby: And you will allow me to defer those questions even though it may not be cross?
Mr. Davis: Yes.
Mr. Darby: Thank you.

HAROLD A. WHEELER, was thereupon recalled as a witness on behalf of the Plaintiff in rebuttal, being previously sworn, testified as follows:

Direct Examination

By Mr. Adams:

Q. There has been some discussion since you testified before, Mr. Wheeler, about the amount of amplification that it was necessary to build into these receivers when they incorporated your system of automatic volume control, and you referred to the Philco 95 receiver, and I believe stated that that had screen grid tubes; is that right?
A. Yes.
Mr. Adams: Now, I may say, your Honor in the stipulated testimony Mr. Earnshaw the chief engineer of the Philco Company testified, and he testified that that receiver had about the same amount of amplification as a contemporaneous receiver which did not use screen grid tubes, namely, the Philco Model 87.
Q. (By Mr. Adams): Now, will you tell us how many stages of amplification there were in the Philco Model 95 and how many stages there were in the Philco Model 87?
A. Before the detector, you mean?
Q. Yes.

A. The Philco Model 95 had three stages of screen grid amplification before the detector, that is of carrier frequency amplification, and the Philco Model 87 had three stages of triode amplification before the detector.

Q. You also referred to the Howard receiver which you modified so as to incorporate your system of automatic volume control. How many stages of amplification before the detector did that have, before you modified it, and how many did it have after you modified it?

A. Before it had three stages, with a triode in each stage, before the detector, and after modification it had four stages of the same type.

Q. Also you refer to the Radiola 64, which was brought out in 1928 and had triode automatic volume control. Did that have screen grid tubes?

A. No.

Q. It had triodes?

A. Yes.

Q. For the amplifiers prior to detection?

A. Yes.

Q. Do you know how many stages of amplification that receiver had before detection?

A. That had five triode tubes in stages. Now, that number perhaps gives a slightly misleading idea of the amount of amplification, because one of those stages I happen to know did very little amplifying, but there were five triode stages before the detector.

Q. There has been some question in the case, Mr. Wheeler, raised as to whether at the time you filed your patent application in 1927 the triode form of detector operated as a square law detector or as a linear detector. Now, can you tell us from your own knowledge, whether it did operate one way or the other, in 1923, in radio broadcast receiver?

A. Yes, I can. In 1923 the triode detectors operated

as square law detectors on small signal voltage. That is the way they were used, I mean.

Q. I seem to have limited my question to 1923. I meant at the time you filed your application?

A. The same is true up to that time.

Q. And did the art ever use or attempt to use the triode detector as a linear detector in radio broadcast receivers?

A. Yes.

Q. When was that?

A. About 1928 there was a tendency in that direction, which was sponsored by some groups of engineers. For example, the Radiola 64 receiver, which I have referred to, used a triode detector operated with high voltages, that is high signal voltage, high "B" voltage, and a relatively large bias voltage, in order to get approximately linear detection over a limited range of signal voltages.

Q. Was that found to be satisfactory in the industry? I do not mean the Radiola 64, I mean that so-called linear triode detection?

A. It had some advantages which were appreciated and which caused it to be used for just a few years, but it still had the overloading limitation and the range of linear operation was not very great, so that that type of detector died out after a few years.

Q. Was it ever used as a rectifier to secure automatic volume control potential?

A. Not that type of operation.

Q. When that type of detection was used, what was it used for?

A. Just for signal detection, that is, for delivering the modulation to the modulation amplifier and the loudspeaker.

Q. Did any of the sets which so used it also have automatic volume control in them?

A. Yes.

Q. What did they use to secure their automatic volume control potential?

A. Another triode rectifier operated in a different manner.

Q. How do you mean, in a different manner?

A. Without such high "B" voltage and "C" voltage.

Q. What were the voltages?

A. Around 45, possibly up to 90 volts on the "B" voltage of the a.v.c. rectifier.

Q. Did that give linear action to this triode when used for automatic volume control in the set?

A. It was not a question of this high voltage giving the linear action, because the triodes were used in a particular way with a relatively large bias voltage; in fact too large a bias voltage to secure linear action.

Q. In other words, they did not secure linear action?

A. That is right, that had some advantages in connection with automatic volume control in other ways, but it was not linear.

Q. Do you know whether the high voltage triode, so-called linear triode, that you have referred to was suitable for use as the automatic volume control rectifier in these receivers?

A. It was less suited than the type of triode that they did use. That is, I do not think either one was very well suited, but this triode linear detector with its very high "B" and "C" voltages would have been more critical and less suited for automatic volume control than the triode arrangement they did use.

Mr. Adams: That is all.

Mr, Darby: I have no cross examination on that subject, Mr. Wheeler.

Cross Examination

By Mr. Darby:

Q. What, in connection with another subject I will ask you, you are the patentee of Wheeler patent number 1879862 and 1879861, are you not?

A. Yes.

Q. And the latter patent, namely, 1879861, was a divisional application of your original patent which has been re-issued into the patent in suit, which divisional application was filed and its disclosure was limited to Figure 6 of the original patent, is that right?

A. That is, Figure 6 is the only one of the original figures shown, and that is the basis for the divisional application.

Q. And with respect to patent number 1879862, the disclosure is confined to Figure 4 of the original patent, is that right?

A. Yes.

Q. And in both of these patents, triode type of automatic volume control is disclosed, and no diode type of automatic volume control is disclosed, in the drawings?

A. Yes.

Q. Have you as a patentee, or has Hazeltine Corporation to your knowledge, ever disclaimed either of these two patents?

Mr. Adams: I can hardly see the relevancy of that, your Honor. I do not want to object to it, but I would like to know what he is driving at. The two patents which are not in suit here at all—

The Court: Well, it is cross examination.

Mr. Adams: I may interrupt your Honor, Mr. Darby says it isn't cross examination.

The Court: That is right.

Mr. Darby: It is not cross examination of the testimony the witness has given now.

The Court: Supposing the witness had answered that question, what would that be evidence of?

Mr. Darby: Both the patents are directed to—

The Court: I understand, but assume that he says that to his knowledge, there has been no disclaimer filed, it would not prove anything, would it, except the limitation of his knowledge.

Mr. Darby: No, sir, because if the disclaimer were filed, he would know, being the patentee, and that is the only way I would have of finding out.

The Court: Would he? He is not the owner, is he?

Mr. Darby: He is an officer of the owner.

Mr. Adams: No.

Mr. Darby: You are not an officer of the Hazeltine?

A. Only of the Hazeltine Service Corporation.

Mr. Darby: Still, if the inventor is alive, your Honor, he would have to sign the disclaimer and he being alive and here, I am asking him.

Mr. Adams: I may say, your Honor, the fact is they have not been disclaimed, I do not see what that has to do with this case.

The Court: All right.

Mr. Darby: I accept that from Mr. Adams just as well as from the witness.

Mr. Adams: In other words, the patents stand without any disclaimer having been filed in either one of them.

Mr. Darby: That is all right. that is all I wanted to find out.

Mr. Davis: I offer in evidence the binder of patents which I directed the Court's attention to.

Mr. Adams: Exhibit 11.

The Court: All right.

Mr. Adams: I have here, your Honor, the testimony which has been stipulated, and it is a photostatic reproduction of the stenographer's transcript in the suit against the Radio Corporation of America. I have bound it in three volumes, because it happens there were separate stipulations relating to it. I do not know how to identify them for the record. I have marked them Volume I, Volume II and Volume III, and in the copy of our findings, which I handed to your Honor today, I have annotated those findings by using those notations. I suggest that we mark them, that we offer them in evidence and mark them here as exhibits, if that seems a suitable practice.

Mr. Darby: It is agreeable with me. May I ask, you are offering the entire deposition, both direct and cross?

Mr. Adams: The entire deposition is to go with the exhibits. Now, I offer in evidence, therefore, the testimony contained in volume one, which is the testimony of Mr. Graham, Mr. Levy, Mr. Cotter, Mr. Johnston, Mr. Curtis, Mr. Dunn, Mr. Farrand, Mr. Earnshaw and Mr. MacDonald, together with the statements concerning the testimony of Mr. McNair, Mr. Defandorf, Mr. Whitman, Mr. Dreyer, and Mr. Taylor, as Plaintiff's Exhibit 26.

(Volume of testimony was thereupon marked as Plaintiff's Exhibit No. 26.)

Mr. Adams: This stipulation relating to that testimony referred to certain exhibits. I am not including them in this volume, because they were identified by Mr. Wheeler and offered in evidence at the time of his testimony with the same numbers as in this volume.

Also, I offer in evidence as Plaintiff's Exhibit 27 volume two of the stipulated testimony which consists of the testimony of Mr. Friis, together with the Exhibits referred to in his testimony.

(Volume 2 of testimony was thereupon marked as Plaintiff's Exhibit No. 27.)

Mr. Adams: Also, I introduce in evidence as Plaintiff's Exhibit 28 volume three of this testimony which consists of the testimony of Mr. Betts, Mr. Fischer, Mr. Nelson, Mr. Scarr and Mr. Browne, together with the exhibits referred to by them.

(Volume 3 of testimony was thereupon marked as Plaintiff's Exhibit No. 28.)

Mr. Adams: I may say, your Honor, that the testimony of Mr. Friis and the testimony of these latter men, beginning with Mr. Betts was introduced in the Radio Corporation of America case by the defendant as part of the defense.

Mr. Crews: Did you include the stipulated testimony of Overacker, Clement, Jensen and Bown?

Mr. Adams: Yes, I did. Also, I should like to state on the record a stipulation which I understand is agreeable to Mr. Darby, and that is that after the decision of Judge Galston on the original Wheeler patent 1879863, the plaintiff, Hazeltine Corporation, promptly asserted that patent against others, and also, as soon as the reissue patent was granted promptly asserted that patent against others, and has continuously asserted it, and that none of those cases has actually been tried, but this was through no neglect on the part of the plaintiff in asserting the rights which it here asserts against the Detrola Company, but was due to the fact those cases were settled.

I don't think I need to state what the cases were unless Mr. Darby wants me to do so, and I don't think I need to state the dates when we filed those suits because I understand Mr. Darby agrees we did it promptly and continuously.

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was the only one that was tried, and that was briefed and submitted to the Court, but was never decided. The fact is that in all of these cases the defendants took licenses. Mr. Darby doesn't like to have me say that, because he thinks I may be urging it as acquiescence in the patent. I don't urge it for that because I don't think it shows that.

The Court: It wouldn't do you any good if you did.

Mr. Darby: There were other considerations which led to the license besides this patent.

The Court: Well, I wouldn't have any right to assume that merely because they were willing to buy their peace for any reason, even if that is any admission, that the plaintiff had any cause of action.

Suppose we take a little recess now and you can look over all your miscellaneous things.

(Recess.)

Mr. Adams: Mr. Darby has furnished us with a copy of the circuit to which Mr. Gates referred in his testimony, as the circuit which he first designed for Detrola after he came from Colonial.

Mr. Darby: I do not believe that is quite right, Mr. Adams. Merely for the sake of accuracy, let me say this; when Mr. Gates was on the witness stand, or, after Mr. Gates left the witness stand there was conversation had with him by both Mr. Adams and myself that does not appear on the record, during which conversation Mr. Adams requested him to produce a copy of the circuit of the receiver he first designed when he came with the Detrola Company, as well as a copy of the circuit represented by the numbers and the letters that he sent to the Radio Corporation and asked them for what markings to make and we told Mr. Adams we would be glad to get all of that and give it to him, and we have given him a copy of each.

Mr. Adams: That is right. And, I ask that that be marked in evidence as Plaintiff's Exhibit 29.

(Document was thereupon marked Plaintiff's Exhibit 29.)

Mr. Adams: With respect to this circuit, I would like to state one thing rather than call witnesses, and I understand Mr. Darby is in agreement with me on it, and that is that the detector in this circuit of the sheet 25-31 marked Exhibit 29, is the tube separate from the first stage of audio-frequency amplification, and is a triode connected as a diode by connecting the grid and plate together.

Also, that that tube served to produce the voltage for the audio-frequency amplifier, and also the voltage for the automatic volume control.

Pardon me, I mis-stated it. It is the plate and cathode that are connected together.

Also, your Honor, in evidence, is the file wrapper of the Wheeler patent 1879863, and a copy of the file wrapper of the re-issue patent. There is none of the parent case, but I would like to state or hand to your Honor a statement, concerning the patents which were before the Patent Office during the prosecution of that parent application. For convenience, I have listed not only those, but also the patents that were before the Patent Office during the prosecution of the original Wheeler patent 1879863, and the patents which were cited during the prosecution of the re-issue patent here in suit.

Would you like to have me state those on the record or have this marked for identification? Maybe I better just read the ones that were in the parent case.

During the prosecution of application serial number 203879 filed July 7, 1927, of which application serial number 495386 filed November 13, 1930 is a division, the

Patent Office prior to the date of division cited United States patents to Espenschied 1447773, Affel, 1511014, Affel 1511015, Appleby 1619911, Friis 1675848, Affel 1677224, Falknor 1698014, Robinson 1733824, French patent 603373 of 1926, proceedings of the Institute of Radio Engineers for April, 1924, page 152, and Experimental Wireless and Wireless Engineer May, 1926, page 328.

That is all, your Honor.

Mr. Darby: Sur-rebuttal, if the Court please; I offer in evidence as Defendant's Exhibit JJ the Wheeler patent 1879861 identified by Mr. Wheeler.

(Wheeler patent 1879861 was thereupon marked Defendant's Exhibit JJ.)

Mr. Darby: And as Defendant's Exhibit KK, Wheeler patent 1879862 identified by Mr. Wheeler.

(Wheeler patent 1879862 was thereupon marked Defendant's Exhibit KK.)

Mr. Darby: And, to complete the story, I offer in evidence as one exhibit, Defendant's Exhibit LL, the four wiring diagrams, produced at the request of Mr. Adams by the witness Gates illustrating the circuits that were sent to the Radio Corporation with request for markings.

(Four wiring diagrams were thereupon marked as Defendant's Exhibit LL.)

Mr. Darby: Likewise, because of reference in the testimony to the original Wheeler patent, we have referred throughout to the original patent of which the patent in suit is a re-issue. As a matter of fact, the original patent which was in suit, was a division of a still further parent application. The parent application matured as a patent on May 18, 1937, number 2080646, and I offer a copy of that patent in evidence so as to complete the story, as Defendant's Exhibit MM.

(Patent No. 2080646 was thereupon marked as Defendan't Exhibit MM.)

Mr. Darby: We have no further testimony.

Mr. Adams: One thing I want to comment on, I think when Plaintiff's Exhibit 17 was marked, there was a whole issue of the proceedings of the Institute of Radio Engineers, and the only thing in that whole volume which is pertinent is the Wheeler paper, and I think we might substitute that, which is only four pages.

The Court: All right.

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Mr. Davis: No one was ever interested in the state of the art prior to the application date if the time of invention has been established as an earlier date, as it has here.

Mr. Darby: In January, I think it was of 1926.

Mr. Davis: Yes.

Mr. Darby: There is no dispute about that.

Mr. Davis: (Reading):

> "43. During the period between the granting of the reissue patent on October 29, 1935, and the filing of this suit March 8, 1938, Detrola Radio and Television Corporation made, used and sold radio receiving apparatus known as Models 175 and 178."

The Court: No dispute about that, is there?

Mr. Darby: No, sir.

PLAINTIFF'S EXHIBIT 26

STIPULATION

It Is Hereby Stipulated by and between counsel for the parties hereto that the testimony hereto annexed (and the exhibits offered in connection therewith) which was taken in the case of RCA Victor Company, Inc. v. Hazeltine Corporation, in the United States District Court, District of Delaware, may be offered by the plaintiff in this case with the same force and effect as though the witnesses personally appeared and testified, subject only to such objections as might be made if the witnesses appeared personally and testified. The testimony hereto annexed and covered by this stipulation is as follows:

Witness	Transcript Page
Virgil M. Graham	344-372 inc.
Maurice L. Levy	468-499 inc.
William F. Cotter	500-508 inc.
Frederick Ernest Johnston	604-629 inc.
Leslie F. Curtis	630-642 inc.
William LeRoy Dunn	642-659 inc.
Clair L. Farrand	747-764 inc.
David P. Earnshaw	764-781 inc.
William A. MacDonald	981-1018 inc.

The exhibits hereto annexed which were offered in connection with said testimony and are covered by this stipulation are as follows:

Plaintiff's Exhibit 13
Plaintiff's Exhibit 14-A
Plaintiff's Exhibit 15
Plaintiff's Exhibit 16
Plaintiff's Exhibit 17
Plaintiff's Exhibit 18

It Is Also Stipulated by and between counsel for the parties hereto that the testimony hereto annexed (and the exhibits offered in connection therewith) which was stipulated in the case of RCA Victor Company, Inc. v. Hazeltine Corporation, in the United States District Court, District of Delaware, may be offered by the plaintiff in this case with the same force and effect as though the witnesses personally appeared and testified, subject only to such objections as might be made if the witnesses appeared personally and testified. The testimony hereto annexed and covered by this stipulation is as follows:

Witness	Transcript Page
Walter A. MacNair	1019-1022 inc.
F. M. Defandorf	1022-1024 inc.
Vernon E. Whitman	1024-1027 inc.
John F. Dreyer, Jr.	1027-1030 inc.
W. H. Taylor, Jr.	1030-1031 inc.

The exhibits hereto annexed which were offered in connection with said testimony and are covered by this stipulation are as follows:

Plaintiff's Exhibit 24-A
Plaintiff's Exhibit 24-B
Plaintiff's Exhibit 25.

It is understood and agreed that if plaintiff offers the testimony of any witness under this stipulation, it will offer the cross-examination of such witness in addition to the direct examination, or, if it does not do so, the defendant is free to do so.

Pennie, Davis, Marvin & Edmonds
Counsel for Plaintiff
Darby & Darby
Counsel for Defendant

Dated: Feb. 24, 1939

The Exhibits referred to in this stipulation were offered separately at the trial and were marked with the same identifying numbers, respectively, as referred to herein and are reproduced in this record as part of the trial Exhibits.

VIRGIL M. GRAHAM, called as a witness in behalf of the plaintiffs, in rebuttal, and having been first duly sworn, testified as follows:

Direct Examination

By Mr. Adams:

Q1 What is your present occupation, Mr. Graham?
A I am director of the Tube Application Department of the Hygrade Sylvania Corporation.
Q2 What is the business of the Hygrade Sylvania Corporation?
A Manufacturer of tubes and lamps.
Q3 You say manufacturer of tubes and lamps. By tubes what do you mean?
A Radio tubes.
Q4 What was your occupation in 1926?
A I was in charge of the Radio Engineering Laboratory of the Stromberg-Carlson Telephone Manufacturing Company of Rochester.
Q5 What was the business of that company?
A Manufacturer of radio apparatus and telephone apparatus.
Q6 How long did you continue in that position?
A Until September, 1935.
Q7 Prior to July of 1926, had you ever heard of a radio receiver employing automatic volume control?
A No, I had not.
Q8 If someone at that time were to come to you and ask you to build such a receiver, what would have been your reaction?

A I would have doubted its possibility at that time.

Q9 Would you have known where to get an engineer to build such a receiver for you?

A Not with any certainty, no.

Q10 In 1926 did you learn of a receiver which did use automatic volume control?

A Yes, I did.

Q11 What were the circumstances?

A If I may refresh my memory with sheets from a diary that was kept at that time—

The Court: Certainly.

A (Continued): On Monday, August 2, 1926, Mr. Wheeler of the Hazeltine Corporation disclosed to me such a circuit which he called at that time the Audiostat.

Q12 Do you find an entry to that effect in your diary?

A Yes, I do.

Q13 Of what does that diary consist, Mr. Graham?

A Daily entries of progress of work in the laboratory and trips I made.

Q14 In what form was it kept?

A Loose-leaf sheets in a Lefax, it is standard Lefax forms.

The Court: Is it yours or the company's?

The Witness: It is mine.

Q15 Your personal diary?

A Yes, sir.

Q16 After Wheeler disclosed to you this Audiostat, did you do anything about building a set employing it?

A Yes. We immediately set to work to build a set and according to the entry in my diary that was completed and tried out on Thursday, August 5, 1926.

Q17 Can you identify the radio set which is now being placed before you?

A It is the Stromberg-Carlson Model 601.

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